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NO. CLVII.—JANUARY, 1882.—VOL. XXVI.

RECENT IMPROVEMENTS IN THE COMPASS, WITH CORRECTORS FOR IRON SHIPS.

By SIR WILLIAM THOMSON, LL.D., F.R.S.

From the "Journal of the Royal United Service Institution."

The improvements which I have made in my compass since the date of my first communication to the Royal United Service Institution (February 4, 1878) have had for a primary object to obtain greater steadiness of the compass in vessels of war during gun-fire, and in steamers generally in which there is great vibration, due to the working of the engines, screw, or other causes. Improvements of some importance have also been made in the system of magnetic correctors for the semicircular and heeling errors, and in the addition of an adjustable Flinders bar for the automatic correction of that part of the semicircular error, which depends on magnetization of the ship by the vertical component of the terrestrial magnetic force at the ship's place. I have also made an improved dipping needle instrument which is much less cumbrous and at the same time more sensitive and more easily used than the marine dipping needle which I described in my former communication.*

In my present communication I shall first describe the mechanical improvements, and then go on to explain their application for keeping the compass as nearly correct as may be for practical use at sea.

* See Journal, vol. xxii., No. XCIV., p. 91, *et seq.*

To produce such steadiness of the compass-card as has hitherto been obtained in steamers which have powerful engines, and where there is much vibration, it has been customary to suspend the bowl by means of india-rubber bands. A serious objection to this method is that the india-rubber is liable to become rotten by exposure to heat or oil, especially if it is used in fine enough bands to give the requisite steadiness in all circumstances. After many trials of metallic springs in lieu of the india-rubber, I at last found a plan of brass spring resembling a rope grummet (A, Figs. 1, 2, 3, 4, 5, 6), but with elastic brass wire instead of the rope strands, by which I succeeded in obtaining more satisfactory steadiness of the compass than with india-rubber. The construction of this brass grummet-ring and the mounting of the compass-bowl upon it, may be described as follows:—A single wire is first bent and its ends are united by soldering or brazing, so as to form a ring of the proper size. This serves as a core on which a second brass wire is laid on spirally, six turns round the core (Fig. 6). The ends of this second wire are also united by soldering or brazing, and thus an elastic ring is produced strong enough to support the compass-bowl. The compass-bowl is suspended from the elastic ring with the intervention of a rigid gimbal ring. The elastic ring has two sockets fixed at the ends of a diameter, which rest on two balls attached to the brass rim of the binnacle stand (Figs. 2 and 4). The elasticity of the ring mitigates the effect on the knife-edges bearing the gimbal ring and bowl, and on the point bearing the compass-card, of vertical tremors of the platform on which the binnacle rests. The knife-edges of the gimbal ring are supported on two grooved stirrups, hung by chains from the elastic rings (Figs. 5 and 6). This suspension mitigates the effect of horizontal tremors of the platform.

Fig. 1

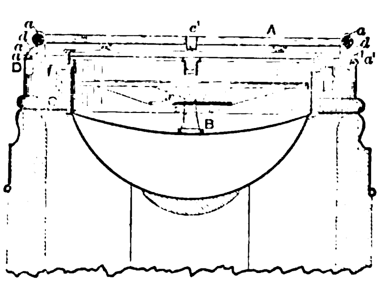
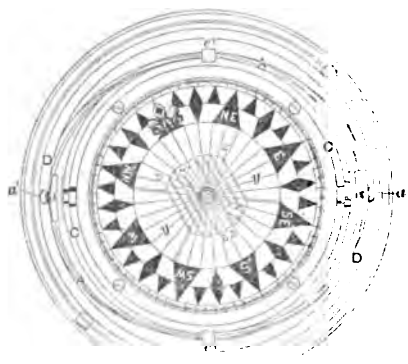


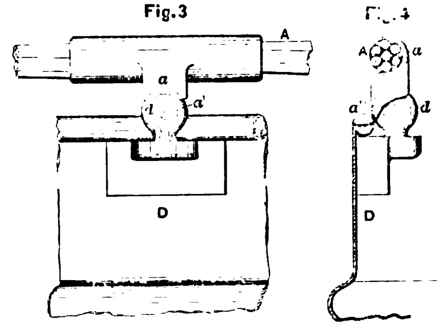
Fig. 2



Figs. 1, 2, 3, 4, 5, 6 illustrate the suspension of the bowl from the elastic ring.

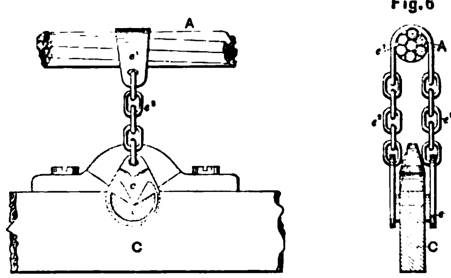
For ascertaining the heeling error I use an auxiliary instrument for comparing the vertical component of the earth's magnetic force on shore with the vertical component on board ship. This instrument is constructed as follows:—Two magnetic needles of hardened steel wire are joined together and supported on two iridium points in a line at right angles to the lengths of the needles, and passing as nearly as may be through the center of gravity of the needles and frame. One of these points rests on a flat support of sapphire or other suitable hard material, and the other point rests in a cylindrically-shaped support of similar hard material.

Fig. 3 Fig. 4



The needles are accurately balanced, so as to be horizontal when resting on the points before being magnetized, and they are then magnetized. The needles are brought to a level position again by a vertical magnet placed at equal distances from the four poles of the needles, and capable of being moved up and down. The position of the vertical magnet, according as it is higher or lower, gives a greater or less vertical force on the needles, the amounts of this force being determined by experiment for different positions of the vertical magnet.

Fig. 5 Fig. 6



This dipping-needles instrument is shown in Figs. 7 and 8; *i i* are the magnetic needles connected together by the framework, *j j*, and supported on the tops of the columns by two iridium points, *k k*.

When the instrument is used in the binnacle, the compass-bowl is taken out and the instrument is put in its place. The instrument is supported by cords from the elastic ring of the compass, which can be lengthened or shortened to adjust the instrument to the level and to the proper height, to bring the needles to the same position as the needles of the compass-card, when the bowl is in its place.

The binnacle, with the arrangement of correctors for correcting the semicircular, quadrantal and heeling errors, is shown in Figs. 9, 10 and 11. M M are the receptacles for the fore and aft magnets; M′ M′ are the receptacles for the thwartship magnets; and H is the Flinders bar. In Fig. 10 the dipping needles instrument is shown hanging in its place in the binnacle.

The binnacle contains mechanical appliances for realizing in practice the principles of correction discovered and published originally by Captain Flinders and Sir George Airey. The correctors for the several parts of the compass error * are as follows:—

To correct the "quadrantal error," a pair of unmagnetic iron globes (solid or hollow), fixed on each side of the binnacle.

To correct the "semicircular error," bar magnets, in symmetrically placed long horizontal † holes thwartships and fore-and-aft within the binnacle, and a Flinders bar (described below) attached to the binnacle outside on the fore or aft side.

To correct the "heeling error," three, two, or one bar magnets in a brass can hung by a chain, by which it can be moved up and down and secured in any position in a brass tube fixed in the center of the binnacle, under the compass-bowl.

The part of the heeling error which depends on magnetism transiently induced by the vertical components of the earth's magnetic force, is always partially and may be wholly corrected by the globes and the Flinders bar. The heeling error on the east and west courses is wholly corrected by the Flinders bar.

The corrector-magnets regularly pro-

Fig.7

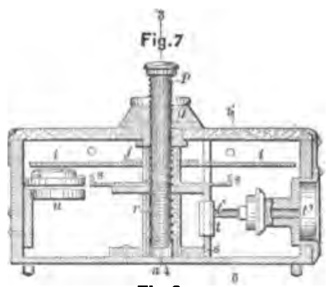
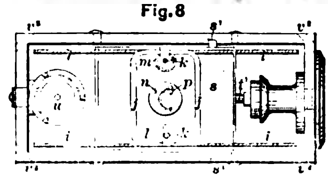


Fig.8



vided with the binnacle for the 10-inch compass are round bars of glass-hard steel, 9 inches long and .4 of an inch or .2 of an inch diameter. Each magnet is painted blue in one half of its length and red in the other half, according to a happy suggestion of Sir George Airy's; blue to mark the end possessing the same kind of magnetism as the earth's north polar regions, and red to mark the end possessing the same kind of magnetism as the earth's south polar regions.*

The fore-and-aft corrector-holes (shown at M M, Figs. 9 and 11) are in two verti-

* "Error of the compass" means the angle between the north and south line of its card and the correct magnetic north and south line. The error is said to be easterly when the north point of the card lies to the east of magnetic north, and westerly when it lies to the west of magnetic north. This use of the word error has official sanction in the Admiralty Manual, Section IV., in respect to the "heeling error." The word deviation is also used in other parts of the Admiralty Manual to signify the same as error, but the word error seems to express the meaning better, and has the advantage of being of two syllables instead of four. Some writers have defined error as the angle between the north and south line of the compass and the astronomical north and south line; but this definition conveys an altogether wrong idea of what the compass ought to do, and is not in any respect convenient. All confusion is avoided by adhering to the simple definition of error given above.

† The words "horizontal" and "vertical," with reference to fixtures in the ship, are used for brevity to denote positions which are horizontal and vertical when the ship is on even keel.

* The blue ends are properly called "true north poles," and the red "true south poles," but (because of the law that likes repel and unlikes attract, in magnetism) the true north pole points south and the true south pole north, if a bar magnet is hung horizontally by a thin thread, and therefore English instrument makers (still unmoved by Gilbert's protest 280 years ago) mark the true north pole S and the true south pole N. All ambiguity is removed in a particularly convenient manner by the Astronomer Royal's blue and red marking.

cal rows or scales, at equal distances of about 5 inches from the middle of the binnacle. The thwartship corrector-holes are in one vertical row (shown at M′ M′, Figs. 10 and 11), about the same distance forward or aft from the center of the binnacle. The holes in each vertical scale are spaced to give equal augmentations or diminutions of corrective force, when one of the corrector-magnets is shifted up or down from hole to hole in order. They are marked with numbers proportional to the corresponding corrective forces.

the thwartship corrector-holes, with blue end to port or to starboard; and a pull forward or aft, by a magnet in one of the fore-and-aft corrector-holes, with its blue end forward or aft. With magnets already in some of the corrector-holes, if a pull to port is wanted, it is had by raising one of the bars in the thwartship scale, if its blue end is to port, or lowering it or removing it or reversing it if its blue end is to starboard; and if a pull forward is wanted, it is had by raising a magnet in one of the fore-and-aft scales, if its blue end is forward, or lowering or

Fig.9

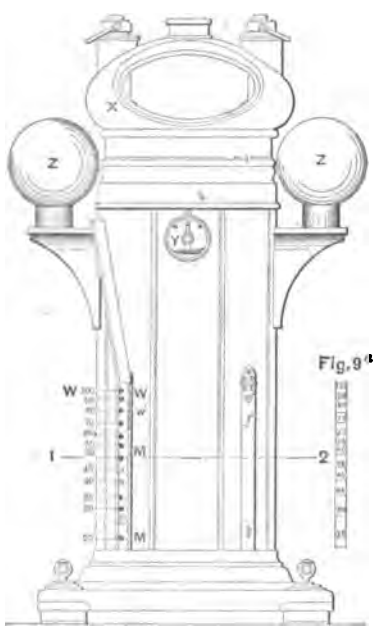
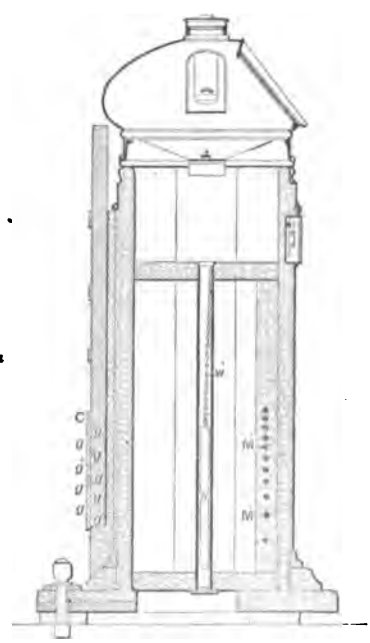


Fig.10



One of the corrector-magnets, when held horizontally with its two ends equidistant from the center of the compass, exerts forces on the ends of the needles in lines parallel to its own length, and in opposite directions on the two ends of each needle. These forces, transmitted through the silk-bearing threads, pull the north point of the card towards the side on which the blue end of the corrector is held. Hence a pull * to port or to starboard is produced by a magnet in one of

removing or reversing it if its blue end is aft.

Westerly error,* when the ship's end is north, or easterly error, when the ship's head is south, is to be corrected by a pull to starboard.

Easterly error when the ship's head is north, or westerly error when the ship's head is south, is to be corrected by a pull to port.

Easterly error when the ship's head is east, or westerly error when the ships'

* A pull to port or to starboard, or a pull forward or a pull aft, is a short expression for a magnetic force pulling the north points of the compass-card to port, or to starboard, or forward, or aft.

* The error is called easterly when the north point of the compass-card is on the east side of the correct magnetic north and south line; westerly, when on the west side of this line.

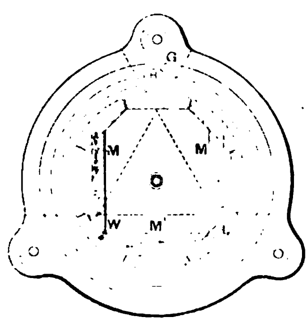
head is west, is to be corrected by a pull aft.

Westerly error when the ship's head is east, or easterly error when the ship's head is west, is to be corrected by a pull forward.

When the globes for correcting the quadrantal error have been once properly placed, no change of this adjustment is ever necessary for the same ship, and the same position of the compass in it, except in the case of some change in the ship's iron, or iron cargo, or ballast, sufficiently near the compass to sensibly alter the quadrantal error. But the magnetic correctors for the semicircular error and the heeling error must be adjusted from time to time, to keep the compass correct.

The Flinders bar supplied with the compass is a round bar of soft iron, 3 inches in diameter, and of whatever length of from 6 inches to 24 inches is found to be proper for the actual position of the compass in any particular ship. To make up the proper length it is supplied in pieces of 12 inches, 6 inches, 3 inches, 1½ inches, and two pieces of ¾ of an inch. In making up the proper length the longest piece should be uppermost and the others below it in order of their lengths. The weight of the bar is supported on a wooden column or bar, resting on a pedestal fixed to the binnacle near its foot, this wooden bar being cut to such a length, or so made up of pieces, as to give the proper height to the upper end of the iron bar. The compound column of iron and wood is kept in position and protected from rain and spray by a brass tube, with upper end closed, going down over it.

Fig. II



The main object of the Flinders bar is to counterbalance the component of the ship's horizontal force on the compass, which is due to magnetism induced by the vertical component of the terrestrial magnetic force. Hence, in all ordinary cases, the ship's iron being symmetrical on the two sides of the fore-and-aft midship vertical plane, and the compass being placed in this plane, the Flinders bar must be placed in it also, and therefore must be exactly in the middle of the front side, or of the after side, of the binnacle. The Flinders bar essentially corrects, wholly and permanently, the constituent of the heeling error, which has its maximum values on the east and west courses. A subordinate object of the Flinders bar, as supplied to my compass, is to partially correct the constituent of the heeling error, which has equal maximum values on the north and south courses, by partially counterbalancing the component force on the compass, perpendicular to the ship's deck, exerted by that part of the ship's magnetism which is induced by the vertical component of the earth's magnetic force. For this object also the proper position of the bar is up and down in the middle of the forward or after side of the binnacle; but for it the bar should be lowered a little below, or raised a little above, the position in which, without altering the length of the bar, it gives its maximum horizontal force on the compass. When it is not desired to make this contribution to the heeling correction by the Flinders bar, it should be placed with its top about 2 inches above the level of the needles of the compass-card.

To understand the action of the Flinders bar, suppose first the ship to be anywhere in the northern magnetic hemisphere.* The vertical force there is such

* The earth's surface is divided into two parts, called the northern and southern magnetic hemispheres, by a line called the magnetic equator, which is the line of no dip. This line is not a great circle like the true equator, but a sinuous line north of the true equator in all east longitude, and from 180° to 173° of west longitude: and south of the equator in all west longitude less than 173°. Its greatest distance on either side of the equator is where it cuts the coast of Brazil, in about 17° south latitude. Its greatest distance north of the equator is in the Indian Ocean, which it crosses from Africa, a little south of Cape Guardaful, to the south of India, very nearly along the 10° parallel of north latitude, and eastward across the mouth of the Bay of Bengal to the Malay Peninsula, still but little short of this degree of north latitude. A chart of lines of equal magnetic dip, such as the very convenient small scale one of the Admiralty Compass Manual, should be carefully studied.

as to pull the red end or pole of a magnetized needle downwards, and to repel the blue end upwards. It also has the effect of inducing magnetism in any mass of iron, so as to give it a transient magnetic quality marked with blue on the upper side or end, and red on the lower side or end. Thus, in the northern magnetic hemisphere the Flinders bar is transiently magnetized by the earth's vertical force in such a manner that it acts like a great bar-magnet, with its upper end blue and its lower end red. At the magnetic equator it loses its magnetism, and in the southern magnetic hemisphere it acquires magnetism in the opposite direction to that which it had in the northern hemisphere; so that now its upper end is red and its lower end blue. As the ship moves from one hemisphere across the magnetic equator to the other, the magnetism of the Flinders bar gradually* diminishes to zero, and then increases gradually in the contrary direction. The object to be attained in applying it to the binnacle is that, with this gradual change of its magnetism, it shall always, as exactly as possible, counterbalance the changing part of the force on the compass, due to the part of the ship's magnetization which changes with the gradual change of the vertical component of the terrestrial magnetic force. If this changing part of the ship's disturbing force on the compass is a pull aft in the northern magnetic hemisphere, and a pull forward in the southern magnetic hemisphere, the Flinders bar must be on the forward side of the binnacle. On the other hand, if the regularly changing part of the ship's force be a pull forward in the northern hemisphere, and aft in the southern hemisphere, the Flinders bar must be on the after side of the binnacle. The former is the most frequent case for the chief navigating standard compass and for the steering compass of modern mail steamers and merchant steamers generally, in which the steering and conning of the ship is done on a bridge forward of the engines, with considerably more than half of the ship behind it. It is also almost certain to be the case for an after-steering compass, a few feet in advance of the top of the iron stern-post and rudder-head, in an iron steamer or sailing ship. The second above-mentioned case is what will generally be found for a compass anywhere in the after half of the ship's length, to within two or three yards of the stern-post. Most frequently it is not possible to ascertain which of the two is the actual case until the ship has made a voyage through regions presenting considerable differences of vertical magnetic force. The best plan generally is, in first placing the binnacle on the deck, to turn it with the fittings of the Flinders bar forward or aft, according as it is found that the fore-and-aft correcting magnets have to be placed with red or blue poles forward or aft. It may be that the experience of a first voyage may show that the binnacle must be turned the other way to get the Flinders bar into its right position; but the chance of this being necessary is less if the binnacle is first placed according to the preceding rule, than if it is placed in the opposite direction without some knowledge to guide. If it has to be turned, the turning is done in a few minutes, for any binnacle made after January, 1880, as the binnacle has four feet, which are screwed by brass bolts to brass sockets fixed in the deck, and fitting for either side of the binnacle foremost.

In the first adjustment, or as long as there is special knowledge as to the proper proportion of correction to be made by the Flinders bar, it may be set to correct about half of the whole error on the E. and W. courses; the remainder must be accurately corrected by the fore-and-aft magnets.

Suppose now the first adjustment to have been made somewhere in the northern magnetic hemisphere, and suppose that as the ship goes to places of weaker vertical force the fore-and-aft correcting force required to make the compass correct on the east or west points, is found to be less than at the beginning of the voyage. It is clear that part of the correction made by the magnets ought to have been made by the Flinders bar. But nothing need be done except to diminish the fore-and-aft pull by the magnets, as long as the ship is going to places of weaker vertical force. If without touching or crossing the magnetic

* The change of polarity in vertical bars in the ship, which takes place in crossing the magnetic equator, has sometimes been falsely supposed to be abrupt, and mistakes in respect to compass courses have been made in consequence.

equator the ship returns again to places of stronger vertical force,* and if it is found that increased longitudinal pull is now required, this should be applied, not by the magnets, but by introducing a Flinders bar or by increasing the bar already in position.

Generally, for a ship making passages to and fro through regions of considerably different vertical force, whether she crosses the magnetic equator or not, the rule in respect of the fore-and-aft correction is as follows:

Correct the deviations found by observation on the east or west courses by the fore-and-aft magnets when the ship is going to places of weaker, and by the Flinders bar when she is going to places of stronger, vertical force, whether in the southern or northern hemisphere.

After a few voyages the proper proportion of correction by Flinders bar to correction by bar-magnets will be practically realized.

Commander CURTIS, R.N.: There are one or two points I should like to mention. A friend of mine, a navigating officer, once told me that he was on board one of our turret ships, and they went out to try her at Spithead. The compass had already been adjusted, but after firing they found the compasses were all wrong. I should like to ask if the concussion of the guns would alter the magnetism of the ship? Sir William Thomson tells us how sensitive the poker is to the slightest tap, and possibly the concussion of our heavy guns, especially being so near the turrets, might alter the magnetism of the ship. I have not been afloat in any ironclad, but I naturally take an interest in the profession, and should like to know how that is. The last time Sir William Thomson spoke with respect to the compass, I wanted to confirm what he said with respect to the blue and the red denoting the *proper* true north and south poles respectively. A merchant captain, in 1864, in command of one of these improved ships, with an iron deck and everything that could possibly be made of iron, on board the ship, was going from the Tyne to Coquimbo, bound round the Horn. The compasses were adjusted, and I presume that he in his happiness thought they would be all right to take them to Coquimbo and back again. But, unfortunately, when he got off the Horn, his chronometer went down, and he tacked always within eight points of the compass. He could not understand it: he put his helm up and ran into soundings, and he literally felt his way into Rio with his deep-sea lead, and he said if he had been at sea another week he would not have had a man left, they were so exhausted. I do not know what the Board of Trade Regulations are with respect to the examination of merchant captains and mates, but I think they should insist that upon the fly-leaf of every log-book, some simple instructions should be given for the correction of the compasses, and also stating for the benefit of the captains, if they do not know it, that when they have crossed the Line, the magnet acts just in the reverse way. One would hardly think that there are any merchant captains who do not know it, but this man certainly did not in 1864. The particular point I wish to ask is whether the concussion caused by firing the guns will alter the whole magnetic attraction of the ship?

Captain SAMUEL LONG, R.N.: I do not feel equal to following Sir William Thomson over the beautiful invention which he has just explained to us: but I must confess that I am very grateful to him for his goodness to the naval profession and the maritime profession at large. I am sure that many now cruizing about the ocean would agree with me in saying that. I should like to ask Sir William Thomson if he could give us any practical results by naval men or merchant captains as to the azimuth mirror for taking bearings, whether it has been found to be practically satisfactory and superior to the old Admiralty plan. Also whether the disturbance of the firing of guns on the compass has been

* "Vertical force" is a short expression for the vertical component of the earth's magnetic force. It is reckoned as positive when the direction of its action upon a red pole is downwards, as in the northern hemisphere; and negative when upwards, as in the southern hemisphere. At the magnetic equator it is zero. The amount of the vertical force at any place is calculated by multiplying the value of the horizontal force given by the chart of lines of equal horizontal force of the Admiralty Manual by the tangent of the dip as given by the chart of lines of equal magnetic dip. Thus, for example, the tangent of the dip for the south of England being 2.44, and the horizontal force there being called unity, the vertical force there is 2.44. The tangent of the dip at Aden is .09, and the horizontal force there is 1.95; hence the vertical force there is .1755, or about $\frac{1}{14}$ of the vertical force of the south of England.

satisfactorily met? The other day I was on board a new steel steamer—one of the newest steamers built—8,000 tons. I said to the chief officer: "What compass have you got?" He said, "We have got Sir William Thomson's." I said I thought it was very costly and difficult to manage. He said, "Oh, no, it is as simple as A B C; we never have any bother at all; it is always correct, and we never have the slightest trouble." I think that information from a practical man, who is constantly at sea, is worth a great deal more than anything I could say.

Lieutenant CHARLES CAMPBELL, R.N.: Without presuming to discuss the able paper to which we have listened, I may be allowed to say that I served two years on board the "Minotaur," which had Sir William Thomson's compass. We found it most valuable in alterations of course of eight points, and, in fact, during all manœuvres. The compass as she came up would settle exactly on the point. The improvements of which we have heard to-night seem to me of the greatest value, and I think Sir William Thomson has given to the Navy a compass that will stand when the guns are in action, and be true to the Pole, he will have done as much for the Navy as if he had discovered the Pole itself.

Staff Commander CREAK, R.N.: Being particularly interested in the compass question on board ship, I propose to make a few remarks on the subject before us. Whilst explaining the construction of his instrument for correcting the "heeling error" on board ship, Sir William Thomson has laid much stress on the importance of knowing or being able to estimate, the value of what is known as λ (lambda), in the notation of the Admiralty Manual. He has given us various estimates of its value from. 6 to .95, according to class of ship. Some of those present to night may not be aware that the Admiralty system more fully recognizes the value of λ by not merely trusting to its being estimated, but by ensuring its being ascertained by actual experiment for every class of vessel in the Navy. The value of the vertical force, or μ (mu) of the Admiralty Manual is also ascertained in every ship. Sir William Thomson also referred in his remarks to the vertical force of ships. His remarks are perfectly clear on the subject, except in one respect, namely, that the vertical force is generally downwards. Perhaps Sir William Thomson has not the same advantage that I have in knowing the magnetic character of every ship of the Navy. The vertical force in her Majesty's ships is more generally upwards, from the fact, that the ships built in our own dockyards are, in most part, built with their heads in a southerly direction. The ship's stern is, therefore, magnetized with red magnetism; therefore the vertical force acts upwards, and that, meeting the downward pull caused by the soft iron of the ship, is in great measure counteracted. I am now speaking of ships such as the larger ironclads (not turret ships), the "Northampton," and similar vessels. Sir William Thomson kindly referred to a paper of mine, that was read before the Royal Society on the question of the effects of the iron masts in the "Undaunted" on her compasses. Although in that case the effects were very important, I do not think it was the cause of the upward force of the "Northampton," because she was built at Elder's yard, on the Clyde, with her head in a southerly direction, and according to the usual effect of the earth upon a ship in such a position, the after part of a ship where the compass is placed, would receive red magnetism, and the vertical force act upwards; but had her compasses been brought near her masts, the upward vertical force would have been very great. The effect of the masts was so great in the case of the "Undaunted," that we had to correct the binnacle compasses by vertical magnets, a thing which has never been done before in a wooden frigate. Sir William Thomson spoke of the large changes of ships going to the Cape, and he very truly said, the Flinders bar was a good thing in correcting that error. He has referred to ships having errors of 30° or 40°. I know of an instance communicated from the Board of Trade, in which there was an error of 40° in a vessel's compass there, which had been correct in Sunderland; but then one must consider, the compass was not placed according to knowledge. It was placed near the stern, and there, of course, it was too near a vertical enormous Flinders bar—the stern-post, a bar affected by the vibration of the ship.

The result was, she changed as much as 30° to 40°. But in our ships, where the compasses, I may say, are placed according to knowledge, the changes are remarkably small. Take the "Volage," for instance. The "Volage," in going from England to the Cape, scarcely altered at all. The change from the transverse force was only 2°. The part that would be expected to change most was from the fore and aft magnetic force, but that only changed 1¾°. That, I conclude, resulted from the judicious position in which the compass was placed; and, therefore, in that case, the Flinders bar would have been of no use. But I can see the use of it when people who build ships will insist on putting their compasses in any place, just as it happens to suit their convenience. There are a few of our ships which have not been so satisfactory lately as the "Volage," the ships of the "Gem" class. The deviations in these ships in going from England to the Cape, have altered as much as 8° to 9°, and, perhaps, there a Flinders bar might have been useful; but not to the same extent that Sir William Thomson has found in merchant ships. Another subject which has been referred to, is the question of firing guns. That has been thoroughly gone into, and the result on iron of firing guns is similar to what you have just seen with the poker. If you put the compass on a thin iron structure, as it is necessary to do in our turret ships, firing guns continually alters the magnetism of that thin iron structure, producing new errors in the compass so placed, and nothing can help it—no Flinders bar or any other magnetic corrector can prevent it, and I should be very glad if anyone will find some system of meeting the difficulty. No man of science has ever brought forward any proposal for preventing the magnetism of iron being altered by concussion from whatever cause. The ships that have altered most have been those of the "Thunderer" class, and we expect it. The captains of these ships are warned accordingly, and especially so. The navigating officer is the officer who has most time to attend to these things, and whose especial duty it is to look after the compass—that compass may be made perfectly correct, and yet after firing, or perhaps, if the ship has been lying in any direction for a certain length of time it is quite enough to temporarily alter the magnetism of the ship. I do not wish to detract in any way from the merits of the compass on the "Minotaur's" poop, which has been mentioned to-night, as it does its work efficiently: but there is nothing whatever to prevent a compass of the Admiralty pattern being put on the poop of the "Minotaur," and being made equally correct to that of Sir William Thomson. In saying this, I wish to point out that we are not behindhand in the Service, but have every means at our disposal for making a correct compass for tactical or other purposes.

Sir William Thomson: Captain Curtis asked a question which has been very clearly answered by Captain Creak. I may add that the "Glatton" showed that effect very remarkably, on the occasion of the particular service squadron under Sir Cooper Key, going from Portland to Portsmouth for the Naval Review in 1878. While steaming out of Portland, my compass on board the "Glatton" was found to be quite correct on all points. Then, by order of the Admiral, the "Glatton" steamed out of position in order to have some trials of the compass under gun-fire. The question as to the steadiness of the compass was satisfactorily answered. The compass remained perfectly steady, and was quite serviceable during the firing of the heavy guns. The question of the effect of the concussion produced by the firing upon the magnetism of the ship was also gone into, and I found an easterly error of 5° when the ship turned to north, immediately after the gun-firing on an easterly course. After a little steaming on various courses, at ordinary speeds, this error became much diminished, if not annulled, in the course of half an hour.

Captain Creak: The compass, when it has been altered by gun-firing, as a rule takes some days to relapse into its former position, but it does relapse gradually.

Sir William Thomson: It is not to be supposed that any *automatic* appliance can be placed on board ship which will cause the compass to point always correctly. My object has been to cause the compass to point correctly by means of adjustment and readjustment performed methodically, by a safe and easy process, when found necessary. The navigator must always be on the watch, to examine the compass and allow for any error he finds. Small changes that may be transitory may be left to themselves, but changes which show themselves, week after week persistently, should be corrected by a slight readjustment of the correctors. Captain Long asked if the azimuth instrument has been found practically satisfactory? I may answer that question by saying, referring to a very satisfactory report communicated to me some time ago by the British India Company, having been received by them from Captain Smith, of their steamer "Malwa," which has had a compass of mine on board. The previous captain had left no record of the errors of any of the compasses, except on the courses actually steered, and Captain Smith joined the ship at a port (Busreh) at the head of the Persian Gulf. With a compass that he had never seen before he naturally felt uneasy, because he was going on different courses to those for which he found the compass errors recorded; and he had absolutely no guidance as to what errors might be expected on the course he had to steer, but he had read my book of "Compass Instructions" during the few days he was in port. Happily, after getting out of port he had clear weather, which allowed him to take bearings of the Pole-star with the azimuth mirror. One important quality of the azimuth mirror is the exceeding ease with which it can be used at night, for stars, even in a heavy sea, with considerable rolling and yawing of the ship. Captain Smith corrected the compass by the magnets, according to the printed instructions, in about an hour. He then put the ship a second time round, and verified that there was no error, and after that he went on his course with full confidence.* He reports that ever since he has had no difficulty in keeping the compass perfectly adjusted at sea. The azimuth mirror has been very extensively used in the merchant service. Captain Lecky, now of the British Shipowners' Company, has taken a great many star azimuths, and reports that he is very much pleased with the results. Captain Long also asked if the performance of the compass was satisfactory during firing? It being perfectly satisfactory in the "Northampton" and in the "Glatton." I have seen it, also, in firing salute-guns in the "Euryalus," and the result has been perfectly satisfactory.

Staff-Commander Creak: May I be allowed, Sir, to add a little to the remarks I have already made, by saying that in any remarks I have made with regard to Sir William Thomson's compass, I hope that the meeting will consider I am not casting any reflection upon it. That compass is now on trial in the "Northampton" by order of the Admiralty, and I am sure it will receive every possible attention and fair play. We shall be glad to hear that it has answered its purpose in every possible way.

Captain Curtis: I think we understand Sir William Thomson to say that this compass will resist firing. That is just what we are told the Admiralty want—a compass which will not be out of order during firing or after.

Sir William Thomson: My compass gives perfectly steady indications during firing; but whatever change takes place in the ship's magnetism by firing, is shown in my compass as in every other compass. Other compasses, however, may be so severely shaken by the concussion of firing, as to break the point or cap; and it is not safe to leave them in position. One great object I have aimed at has been to provide a compass which need not be lifted off the bearing point during firing, and which can be used for navigation of the ship during gun practice or in action.

The Chairman: There is one remark made by Sir William Thomson which I think all those who have to navigate ships should lay to heart, and that is, that notwithstanding all his ingenious arrangements and improvements of the compass, he dwells upon constant observation, constant care, and constant watchfulness, to see that the errors are corrected. I have heard that it is not, perhaps, so much attended to as it should be in the merchant service. The officers of that service too often have their compasses corrected by experts at home, and pay very little more attention to the matter. It is manifest, that whatever may be the ingenuity displayed in correcting compasses, nothing can supersede careful observations. I think we are all deeply indebted to Sir William Thomson, a man of high scientific attainments, for coming here this evening, and explaining this very interesting in-

* "I had done in one short hour on a dark night with this new compass what would have been simply an impossibility under the same circumstances to have done with an ordinary compass."—Extract from report of Captain H. B. Smith, dated Calicut, Feb. 15th, 1880, to the British Indian Steam Navigation Company.

strument. We have heard a most instructive paper, and hope, as Captain Creak has expressed it, that the compass now on trial may prove as great a success as Sir William Thomson wishes it to be. With your approval, I will return our grateful thanks to Sir William Thomson for his very valuable paper.

THE UNITED STATES SIGNAL SERVICE.

Abstracts from the Report of the Chief Signal Officer, GEN. M. B. HAZEN, to the Secretary of War.

The Signal Service has had its growth in the generous support of the American people, and year by year an increased confidence has been shown in the usefulness of its work; a confidence that has steadily augmented with the development of the Service. The Weather Service of the United States has been without a rival in the practical advantages derived from its labors, but the day has now come when it should take its stand among the foremost, in the scientific study and investigation of the higher branches of theoretical meteorology, and it is upon such investigations intelligently pursued that the hope for greater benefits must mainly rest. I have endeavored to bring this Service into active sympathy and co-operation with the ablest scientific intellects of the country. In this direction, and in response to my request, the National Academy of Sciences has appointed an advisory committee of consulting specialists with which I may confer as occasion demands. I take pleasure in acknowledging this courtesy as showing the establishment of more intimate relations between the scientific interests of the United States and the Signal Service.

This year has been distinguished by additional progress and by decided improvement which I will briefly recite: The establishment, under your sanction, of a permanent school of instruction at Fort Myer, Va.; the raising of the standard of the personnel of the Signal Corps; the systemization of the duties of the Signal Service; the preparation of new instructions for observers of the Service; the preparation of new and improved forms for the recording and preservation of meteorological data; the preparation of special bulletins for the press, containing weather information of public interest; the forecasts of weather, of hot or cold waves for periods exceeding twenty-four hours; the forecasts of "northers" for the interior plateau; the adoption of a new storm signal (the Cautionary Northwest) for the interior lakes; the arrangement for increase of river service, and wider publication of warnings of floods or ice gorges; the changes and improvements in the publication of the "International Bulletin," and the "Monthly Weather Review," with their accompanying charts; the increased information added to the "Farmers' and to the Railway Bulletins;" the organization of a service for the special benefit of the cotton interests of the South; the extension of the special frost warning to the fruit interests of the country; the investigations into thermometric standards, and into barometric standards; the preparation of new hygrometric tables containing correction for altitude; the revised determinations of the altitudes of Signal Service stations; the computation of monthly constants for the reduction of observed barometric pressures to sea level; the arrangements for original investigation in atmospheric electricity, in anemometry and in actinometry, and, in the last subject, especially with reference to the importance of solar radiation in agriculture and the absorption of the sun's heat by the atmosphere; the co-operation in an expedition to the summit of Mount Whitney, California, for the determination of problems in solar physics; in metrology, the preparation of conversion tables for the English and metric systems; the co-operation in the dropping of time balls at Signal Service stations; the publication in quarto form of special professional papers; the offering of prizes for essays of great merit on meteorological subjects; the organization of State weather services; the new investigation of danger lines on Western rivers; the organization and equipment of two expeditions for meteorological observation and research in the Artic regions of America, one to be stationed at Lady Franklin Bay, the other at Point Barrow, Alaska, both co-operating in this work with a system of stations established in the Polar region by international conference; the establishment of a system of stations of observation in Alaska; the arrangements for organizing a Pacific Coast Weather Service; the display at the Paris Electrical Exposition; the experiments for improving newspaper weather charts; the increase since June 1st of telegraphic weather service, exceeding in value $34,000 per annum, without additional expense to the United States, and the extension and construction of military telegraph lines.

All these subjects are treated in full in the body of this report.

There has been continued at Fort Myer, Va., the established course of theoretical and practical instruction in military signaling, in international signaling, in the use of different ciphers, in military surveying and the use of surveying instrumeuts with topographical mapping, in electricity and the electric telegraph, in telegraph practice, in the construction of telegraph lines, on land or under the sea, and in meteorology.

Experiments in signaling and telegraphy are made at Fort Myer under proper supervision. It is endeavored to keep up in all improvements with the progress made by scientific ingenuity in the special duties of the service, in the use of improved war material, and in the different modes of rapid communication now necessary and expected to be used in war. With each ensuing year the duties of corps analogous in their service to the Signal Corps, become more prominent, and hardly a month passes without some suggested improvement in telegraphic or signal apparatus, or in the methods of using them. Such are here tested as may have received the notice of this office, or to which attention is directed by higher authority. It is by following plans determined by tests made at this office and at Fort Myer that the proper construction of the iron lines now so successfully used on the sea coast and for the connection of posts, settlements, and stations on exposed frontiers and in the uninhabited interior has been secured.

A series of experiments has been made with sun flashes, with a view of improving upon the forms of heliograph to be adopted for the general uses of the Army, and it is believed that the improved heliograph selected combines great simplicity with efficiency, and possesses many practical advantages, so far as known, over similar instruments in other services.

The importance of the field duties of the Signal Service, and of the modes of communication such services make possible, are now recognized throughout the world. The modes of instruction in field or out-door signaling, now nearly similar in the Army and Navy of the United States, ought to be made absolutely so, and a course established so complete that any force of either arm will be surely competent at any time to put itself in signal communication with any other force, either of its own, or of the other arm, within signal distance. It is not necessary now to represent at length to any who are familiar with the operations of recent warfare the propriety and the need that an armed force of any army should be able to telegraph to, or to communicate by signals with, any other force of the same nationality, or obeying the same general command.

The habitual practice of the more simple duties of field signaling and telegraphy ought to become a part of the regular exercises adopted for the militia forces of the different States. To a small extent this practice has been already entered upon in some of the States.

The enlisted men of the Signal Corps are engaged on duty as constantly in time of peace as in the presence of actual war. The uses of the post at Fort Myer, for the discipline and instruction of the officers and enlisted men of the corps, do not cease while they remain in the service. The force, made useful in time of peace by employment through which it returns to the United States more than the cost of the service, is kept in readiness for any emergency of armed duty by regular drills, in which the officers and men stationed at this office, and those whose changes of station bring them even temporarily within reach of Fort Myer, are occasionally joined.

The advantages of distributing in the different cities of the United States a force of men, with such training, habituated to acting promptly and in concert, capable of reporting by telegraph and in cipher, as a duty, upon matters of military interest to which their attention may be directed, aside from the routine duties of their station, have been sufficiently manifested. The self-possession of the non-commissioned officers in charge of stations, their prompt, concise, and reliable reports, rapidly collected over great extent of territory, for the information of superior authorities, in emergencies which have occurred, have received the warm commendation of officers high in rank. To rapidly make reports of this character and to collect them over the telegraph wires, by ærial signals, or by other methods of communication, is the especial duty required of the Signal Corps in time of war, and its services have been made available for the collection of trustworthy information during great national excitement in time of peace.

The legislation of the act approved June 16, 1880, increasing the enlisted force of the Signal Corps by fifty additional men, has been and will be productive of good results. This and previous legislation has fixed the service on an honorable footing, and opened a reputable career to the best class of young American citizens. The applications for enlistment are numerous. The severe examinations are successfully undergone. The clause providing "that two sergeants may in each year be appointed to be second lieutenants," gives that stimulus of permanent service and promised reward so long and earnestly sought for.

The work aggregating at the office of the Chief Signal Officer has become each year more extensive. A field of operations actually co-extensive with the northern hemisphere is now within its scope.

The details are many and complicated, each requiring to be elaborated with the many checks necessary for accuracy, and each limited for its discharge to fixed and brief periods of time.

The organization of the service, improved by experience, has permitted each branch of duty to be carried on with regularity. The force on duty at this office, small in view of the onerous and extensive duties devolved upon it, has been at times, and necessarily, overworked,

In rendering these duties it ought to be borne in mind that they are continued day and night without cessation for holidays or days of rest. There is no single day of the year in which the work is suspended. It must of necessity and for this reason be performed by details of men who relieve each other at fixed times. The total force employed at this office numbers one hundred and ten enlisted men,

In estimating the numbers required to be present for duty, it is difficult to make a comparison between an establishment thus conducted and others in which the work is limited to certain hours of daylight only. This office is the center to which the daily and nightly, weekly and monthly contributions of all other offices or stations of the Signal Service, scattered throughout the United States, tend to be daily condensed, and finely elaborated and made of practical value. There are concentrated, also, the reports from the five hundred and eighty-two places at which voluntary reports of daily observations are now made on this continent, and from three hundred and six locations in foreign countries from which reports of daily simultaneous observations are had. From the great mass of data thus collected, and which enhances each year in value, are continuosly elaborated the results which appear in the different issues of the office, whether in the form of forecasts telegraphed to the press throughout the country; of charts or bulletins distributed hence; of generalizations announced as apparent; of cautionary signal orders, or the weekly and monthly publications. No single report of any observation received at the office fails to receive attention or study.

The total number of daily reports, of all kinds, now received and filed at this office, is as follows: Number of daily service telegraphic reports, 247; number of international daily simultaneous reports, 521; number of reports from voluntary observers, 334; number of reports received from the Medical Corps of the Army, 83; number of reports received from United States Naval Observers, 36; making a total of 1,221 reports received regulary for discussion.

It is from this office that the management and supervision of telegraphic lines, erected and now worked by the United States, upon the Indian frontier and in the States and Territories of the interior is controlled. The wires of the coast lines have here their terminal connection, and here concentrates the labor of the different coast stations. Upon this office devolves, and with each year to an increasing extent, the duty of transmission of many and important messages from superior authorities to and from distant posts and parts of the United States, for the safe delivery and proper guarding of which, by cipher, if need be, this office is responsible. The rooms of the telegraphic department are never closed or left without an operator. The brief narration possible in a report of this character can convey but little idea of the various and incessant labors incident to such an establishment.

The *Scientific and Study Division*, which was established January 27, 1881, for the purpose of scientific research and investigation into the laws of meteorology. Connected with this division are consulting specialists, who are employed as occasion may require. To this division also are referred all questions relating to standard measurements, altitudes of signal stations, and the preparation of tables for the reduction and conversion of meteorological observations.

ECONOMY IN ADMINISTRATION.

I have undertaken the thorough systematizing of the work in the Property and Disbursing Division of this office, and to secure the more economical expenditure of, and more ample checks upon, the disbursements of public money. Much has been already accomplished, and it is believed that large savings can yet be made in the efficient administration of the bureau, by still further substituting the mail for the telegraph, by a more careful condensation of sentences used in telegraphing; by revision and substitution of arbitrary cipher codes; and by the proper omission of certain telegraphic reports. By a complete revision of all the telegraphic circuits used by the bureau, without an actual reduction of the pay roll of the telegraph company, we have, without any additional cost, secured service in providing information for all the large cities that is essentially necessary to them, and was constantly called for, and that would otherwise have cost thirty-four thousand dollars. This is practically a saving of that amount. I have since endeavored also, by making the assignment of observers at stations more permanent, to reduce by a large sum the cost of transportation of these men from place to place. On account of the very rapid enlargement of the service of this bureau, the amount thus saved to the United States will not appear as large in my annual estimates as it otherwise would, but I will still endeavor to reduce them by seventy-five thousand dollars for the two items, the maintenance of the weather bureau and telegraph lines, below the cost of the past current year, and I have reasonable hopes at a later period to make still larger savings.

STATION DIVISION.

Signal-Service Stations.—The total number of stations of observation in June 30, 1881, within the territory of the United States and maintained for the Signal Service, was two hundred and ninety-six, including those upon the telegraph lines in charge of this office, and the special river and sunset stations, from which reports are regularly received. Reports are also received from seventeen additional stations established by the authorities of the Dominion of Canada, also from one at St. John's, N. F., and one at York Factory, B. A. Telegraphic reports have been regularly received throughout the year from one and mail reports from two stations located in the West India Islands, and during a portion of the year telegraphic reports from five and mail reports from three others. The number of stations from which telegraphic reports are received at this office tri-daily is one hundred and forty-two, the number from which one telegraphic observation only is received daily is twenty-eight, and from which two telegraphic reports are received daily is one; making the total number of separate points from which telegraphic reports are received daily, one hundred and seventy-one.

The sums expended for the service secure for the United States not only the reports from the officially-established stations, but incidentally those had from the additional stations, to which reference is made elsewhere.

The territory of the United States is not yet covered with stations as it ought to be, and valuable opportunities for study, which must be made good hereafter, and at an increased expense, are lost. The field of labor has increased greatly each year, as it has been learned how labor may be turned to the best benefit of different classes of citizens. The number of stations established in Alaska has been increased in response to numerous demands. The amount estimated as necessary to be appropriated for this service for the ensuing year, the sum of three hundred and fifty thousand dollars, can be wisely expended. The whole working force of the corps, five hundred men, will be constantly employed, and, in some instances, overworked. The services of citizens, in addition, will be needed as in preceding years.

The reports of observations had in ceaseless succession from the stations already established, while daily and primarily employed in the studies needed for the daily issuing of forecasts and the display of cautionary signals, form also the basis for future work, to be of equal value with that made possible by the first use of them, and to constitute a record, to increase in worth hereafter with every year for which it is continued.

The duties of the enlisted men at each station are as follows:

At stations forwarding telegraphic reports they are required to take, put in cipher, and furnish, to be telegraphed tri-daily on each day, at different fixed times, the results of observations made at those times, and embracing, in each case, the readings of the barometer, the thermometer, the wind velocity and direction, the rain gauge, the dew point, the character, quality and movement of upper and lower clouds, and the condition of the weather. These observations are taken at such hours, at the different stations, as to provide the three simultaneous observations taken daily at three fixed moments of physical time throughout the whole extent of the territory of the United States.

On November 18, 1879, the times of taking the morning telegraphic observations were changed to a time thirty-five (35) minutes earlier, viz.: from 7 hours 35 minutes A. M. to 7 hours A. M., Washington mean time. On the same date the times of taking the afternoon telegraphic observations were changed, so as to be taken one (1) hour and thirty-five minutes earlier, viz.: from 4 hours 35 minutes P. M. to 3 hours P. M., Washington mean time.

These changes were made in order that the intervals between the observations should be uniform, viz.: eight (8) hours, it having been impracticable to change the time of taking the 11 hours P. M., Washington mean time, observations.

Observations, however, continued to be taken at 7 hours 35 minutes A. M., Washington mean time, at all the Signal Service stations, for the bulletin of International Meteorological Observations, until the change of time was made by foreign observers on January 1, 1881.

In addition to the three telegraphic reports, two, taken at hours simultaneous, viz.: 11 A. M. and 7 P. M., Washington mean time, are made and recorded at each station.

A sixth observation is required to be taken at the exact hour of sunset at each station. This observation, which calls for a careful study of the western sky, and such other local signs as may presage fair or foul weather for the ensuing twenty-four hours, is reported with the midnight observation.

At the stations at which cautionary signals are displayed, an observer must be constantly on duty to receive the order and to show the signal, which may be ordered at any moment. At stations from which river reports are furnished, an observation and record of the depth of the water is made and reported at a fixed hour on each day. In cases of threatening storms or dangerous freshets, any station may be called upon to make hourly reports. In cases of violent thunder storms, reports are sometimes required to be made hourly during its continuance.

FARMERS' BULLETINS.

The plan of exhibiting as widely as possible in the agricultural districts throughout the United States, the results of the daily office studies, in the form of printed forecasts for the benefit of the agricultural populations, frequently described in former reports, has been continued in operation. The effort to cover so wide an extent of territory has made the labor great. This publication contains a synopsis of the weather conditions which have prevailed over the United States for the preceding twenty-four hours, as well as selected "Indications" of interest to the respective districts where these bulletins are circulated. The continuance of the work has been warranted by the favor with which it has been received. It has been considered due to the farming populations that they should have an opportunity to profit by whatever information could be given them. With the active co-operation of the Post Office Department, with which there is an arrangement for this purpose, six thousand six hundred and seventy-two Farmers' Bulletins, on which have appeared the reports of this office, have been distributed and displayed in frames daily at as many different post-offices.

The information given on these bulletins has a value in addition to the synopses and forecasts. The general law accompanying weather changes in the United States and facts relating to the climatology of the different sections are condensed into brief notes, which are published with the telegraphed reports. For instance, each bulletin announces for the geographical district in which it is displayed, what winds in each month have been found most likely and what least likely to be followed by rain at the stations within each district. Diagrams, showing the circulation of winds out of a high and also into a low barometer, also appear upon these bulletins. These simple foot-notes have their effect in increasing the gains and reducing the losses of harvesting. These bulletins will improve for the uses for which they are intended, as the experience of the office permits the information they exhibit to be supplemented with further data and other rules. With each year the popular knowledge of the uses of the bulletin and the increased interest in and study of meteorology, render the farming communities better able to judge of its correctness and to benefit by its contents. It is contemplated, as the work of the office progresses, to add to the bulletin such brief instructions as may be practicable in regard to its uses in connection with such instruments as may be attainable for local observations. Reference has been made in preceding reports to the economy of this work. Careful estimates have shown that if the cost for each station at which the bulletin is displayed was computed to be twenty-seven cents per day, the total sum would meet all the expenses caused by the Signal Service. A little saving on one crop of grain made on any one day in the vicinity of each station, supposing nothing to be saved on any other day of the year at or near that station, would more than counterbalance the expenditure.

REPORTS FOR THE BENEFIT OF THE COTTON INTERESTS.

In compliance with the promise contained in the last Annual Report, to largely increase the usefulness of this Service to the great cotton interests of the South, a correspondence was opened with the representatives of the Cotton Exchanges to take into consideration the advisability of establishing a large number of auxiliary stations in the cotton belt. The plan contemplated was that these auxiliary stations should be situated on railroads, or at points having general telegraphic communication. The railroads traversing the cotton belt were requested to co-operate by requiring their agents, at selected stations, to take, as a part of their railroad duty, rain-fall and temperature observations, which were to be telegraphed free, as railroad business, daily, to selected centers, for distribution at the expense of the Signal Service, to the Cotton Exchanges in all important cities in the cotton region. To railroads undertaking co-operation, the Signal Service promised to furnish rain-gauges, maximum and minimum thermometers, instrument shelters, and the necessary stationery. The proposed system would ensure to all exchanges concerned complete and accurate information, each morning, as to the meteorological conditions existing in the entire cotton-growing belt. The railroads owning their own telegraph lines responded very generously to the appeal made to them. On other roads, where the lines were owned by the

Western Union Telegraph Company, the question was raised if, under the conditions of the contract between the railroads and telegraph company, weather reports could be transmitted free to the centers of distribution. Upon representation to the Western Union Telegraph Company, it, with great liberalty, consented to the free use of its wires for this special purpose. All the earlier difficulties attending the organization of this Service were speedily and favorably adjusted. Two hundred and forty-eight auxiliary stations were promised, which opened to the United States a very favorable opportunity for obtaining meteorological data, at a very slight expense, from a region whose agricultural interests depend, to an unusual extent, on climatic conditions, not yet as well understood as they should be. Unfortunately Congress did not appropriate the amount which had been carefully estimated as necessary to meet the expense of the increased work proposed for the signal Service, and I was very unwillingly compelled to reduce the number of stations to be established to one hundred, selected from the two hundred and forty-eight stations promised, which are so situated as to best cover the cotton belt. I very earnestly hope that Congress will this year provide the funds necessary for a great extension of this special feature of the Signal Service, which promises, with a very small expenditure, such great practical advantages to the staple interests of the South.

Special Bulletin.—This year, for the first time, the Chief Signal Officer has caused to be prepared and issued, twice daily, special bulletins for the press, containing meteorological information, of popular interest, to a greater extent than can appear, for want of space, in the official synopses and indications. They treat especially of high winds, severe storms, tornadoes, heavy rain-falls, floods, extreme temperatures, sudden and great changes in temperature, frosts, temperatures specially reported from health resorts, during the season when frequented, and, when the conditions sufficiently warrant, fair or rainy weather, as the case may be, predicted for two days in advance. There are also forecasted the movements of the so-called "warm waves" and "cold waves."

In addition, the Chief Signal Officer causes to be regularly made, daily, each morning, by all officers who are liable for detail in the Indication Division, forecasts or deductions of the weather conditions for the day succeeding that on which the forecasts are made. If the result of these studies is sufficiently successful, indications will in time, be issued for all districts for periods of more than one day.

The confidence of the people, as a whole, has not been sensibly lessened at any time, by the errors and omissions which sometimes occur, owing to the fact that in the present condition of science, and with a system of observation still too limited, premonitions having for their scope a territory so great as that of the whole United States, and embracing the coasts of two oceans, cannot always be correct for every part of a district.

RIVER SERVICE.

The river reports, giving the average depth of water and notices of the dangerous rises in the different great rivers of the interior, for the benefit of the river commerce and the populations in the river valleys, have been regularly made, telegraphed, bulletined in frames, and also published by the press at the different river ports and cities.

The manner in which these reports are prepared and used, and the mode by which a "danger line" has been determined with water below which there is considered to be no danger, while every rise above it is dangerous, have been sufficiently explained in preceding reports.

The information published in reference to this danger line, in connection with the daily reports of this office, has, on the occurrence of river floods, enabled those interested to judge of the probable limits of the rises of water to be expected at the different places on the river-banks, and of the dangers to be anticipated. This knowledge has made possible necessary precautions for safety.

The data received at this office from stations making river reports permit a foreknowledge of changes likely to happen, and make it possible to give useful warnings of coming floods, ice-gorges, or of sudden and great rises of the river water-levels. The daily reports are also useful at times of low water, the information they then give permitting river shipping to be moved with intelligent foreknowledge of the probable depths of water to be found in the river channels at different points upon the river's course. These reports, having an official character, are especially useful to those for whom they are intended.

In instances which have attracted the attention of this office, the notices of the probable heights anticipated or passing floods would attain have been followed by preparations made to guard against danger. A brief examination of the charts of changes of the river levels, accompanying this and preceding reports, shows that the river rises to occur at the different localities, and their extent can be judged of frequently by the conditions existing at points sometimes far distant. Accumulating data render studies of this kind valuable. In connection with these studies the examination of the daily weather-charts, showing places at which precipitation has occurred or is likely to occur, and the amount of such precipitation, had with the study of the charts of the river basins, which enable it to be determined what rivers will be affected by precipitation, are to be found of value in furnishing correct prognostications.

The opinion is again expressed that with proper study of the river floods, and with stations properly placed, reporting at times of especial danger, it can be made almost impossible for a flood to follow a river course without notice being given, in advance of its coming, to the localities threatened.

FROST WARNINGS.

In November, 1879, for the first time, special frost indications were ordered to be forecasted and telegraphed from this office to New Orleans, for the benefit of the sugar interests of Louisiana. Special attention has since been given to the early forecasting of anticipated frosts for the sugar regions from the 1st of October to the 1st of February of each year. The warnings are given as early as they can be with reasonable safety; if possible, three days in advance. This information is telegraphed to the observer at New Orleans, and immediately upon the receipt of the message announcing anticipated frost, it is furnished to the press, bulletined at the Cotton Exchange, sent over the city by telephone, telegraphed to interested towns and parishes, and, where no other facilities are available, the information is sent by mail. The success of the special forecasts for the autumn of 1880 is sufficiently shown by the following resolution passed by the Chamber of Commerce of the city of New Orleans:

"*Resolved*—That the action of the Signal Service in giving the recent frost warnings, which enabled our sugar planters to guard against injury to their crops, deserve the approval of the planters and merchant factors of Louisiana, as having added to the confidence of investment and to the value of the culture of a staple important to American independence of foreign supply."

The Chief Signal Officer, by reason of the success of the frost forecasts for the benefit of the sugar interests of Louisiana, has been encouraged to undertake this year, for the first time, similar warnings for the benefit of the Orange interests at Florida, and also of the fruit interests of other points exposed to danger from frosts.

The co-operation of the Navy of the United States in the taking of observations simultaneously and in accordance with the system adopted at this office, wherever naval vessels of the United States may be, as established by the general order of the Secretary of the Navy, dated December 25, 1876, has largely increased the data of this class. This co-operation has been skillfully rendered by the Navay Department and the United States Navy, through the commanders and officers of vessels and the Chief of the Bureau of Navigation.

The people of the United States are thus the first nation whose Army and Navy co-operate, as all armies and navies should, under official orders, in the taking of simultaneous observations wherever the forces may be. This co-operation has now existed for nearly five years.

A copy of the daily International Bulletin exhibits the character of the international reports and that of the information had from each station. The charts accompanying these bulletins show, as nearly as practicable, the locations of the stations and foreshadow the studies which the reports taken from them will make practicable.

The average number of daily simultaneous observations now made in foreign countries is three hundred and six. The total number of stations on land, and on vessels at sea from which reports are entered in the bulletin regularly is five hundred and twenty one. The co-operation of the different nations, secured by this plan of exchange, has rendered the additional cost to the United States of this grand system of reports but little more than that of the cost of the preparation, paper, and binding of the International Bulletins and the accompanying charts, at a cost which would be incurred in great part for the proper presentation of the records themselves, even if these bulletins were not distributed.

The issue of the daily International Weather Map was commenced July 1, 1878. Each daily chart is based upon the data appearing upon the International Bulletin of same date. The charting extends around the world and embraces for its area the whole northern hemisphere.

The daily issue of a chart of this kind, thus issued for the first time by the United States, was without a precedent in history. It exhibited the co operation, for a single purpose, of the civilized powers of the world north of the equator.

Actinometry. — I. — Importance to Agriculture.—It is well known that the ordinary observations of temperature have only a very general relation to the growth of plants, which latter depends upon the direct action of the sun's rays; this is especially true of the ripening of grains, fruits, and vegetables, and some means of recording the direct effect of the sun's rays has long been a desideratum to the student of the relations between agriculture and meteorology. The simple apparatus, known as the conjugate thermometers of Arago and Marié-Davy has, by experience, been found to fairly answer the necessities of this study, and 20 Signal Service stations have been selected as proper to be furnished with this apparatus. The results of observations at these will doubtless materially contribute to the decisions of questions relative to the adaptability of the respective sections of the country to certain grains, &c. The bearing that these observations have upon agriculture is illustrated in translations by Professor Abbe from recent European periodicals.

But, beside the important bearing of actinometric observations upon agriculture, they are considered of fundamental importance in the study of meteorology itself. I have, therefore, supplemented the conjugate thermometers by ordering an absolute actinometer, as invented by Violle, by means of which the total quantity of heat received at any one time and place is determined.

II.—Professor Langley's Expedition to Mount Whitney to Study the Absorption of the Sun's Heat by the Atmosphere.—The importance of this subject, mentioned in the preceding paragraph, justifies the most thorough examination of the questions—What becomes of the solar heat received by the earth's atmosphere, how much of it is absorbed or retained in the upper air, where it has an important office to perform, and what part reaches the surface of the earth where its effects are equally manifest? According to the recent researches of Professor S. P. Langley, aided by the delicate "Thermo Electric" apparatus, devised by him, the amount of solar energy that is absorbed in the upper portions of the atmosphere is vastly greater than has hitherto been suspected, and, as the questions raised by his investigations could best be answered by means of observations made on the summit of high mountains, I have considered it my duty to further the solution of these fundamental questions by furnishing him every facility in my power to make the necessary observations. To this end Professor Langley and his delicate apparatus have, with your permission, been transported to the summit of Mt. Whitney, California, where he now is, at an altitude of 15,000 feet, and the observations made by him will, undoubtedly, determine the questions that have been raised.

METROLOGY.

II.—The Metric System.—In general the laws of the United States legalize the adoption of the metric system, and a growing disposition is believed to exist favorable to its use when necessary. It would seem that the work of the meteorologist is almost doubled by the labor involved in the mutual conversion of English and metric measures, and as the metric system is one thoroughly rational and well grounded in every step of its development, and as the accuracy of its standards surpasses that of the English system, it is evident that in the meteorological work of this office, whose measures of to-day should be perfectly comparable with those of a century hence, an advantage would result from the adoption of this system of measures, which is in fact now used by meteorologists of all the world, except a portion of those of Great Britain and the United States. Nothing has contributed more to illustrate the intrinsic value of this system than the establishment in 1875, by the United States and other Governments, of the International Bureau of Weights and Measures.

As the metric system is fully legalized by the action of Congress, is taught in most schools, and is very widely adopted by architects, chemists, naturalists, engineers, the United States Coast and Geodetic Survey, the Internal Revenue, Post-office and Treasury Departments, I am, therefore, led to anticipate that it will ere long be incumbent upon this office to also adopt that system, at least in its scientific meteorological work.

The question is, however, one which I propose to refer, through you, to the National Academy of Sciences, as the adviser of the Government in science.

III.—Standard Time.—The importance of securing simultaneity of Signal Service observations has made it an object of solicitude as to what means are practicable and best in order to attain this end. Hitherto it has been the custom to instruct the observers to keep their clocks so regulated as to indicate local time, but on account of the great variety of times in use in many localities, much uncertainty has arisen as to what should be called the local time of the locality; thus, for instance, in New Haven the time ordinarily used has been, for many years, coincident with that used in New York and New Haven R. R., and is, therefore, several minutes slower than the proper time to its own meridian. Among the voluntary observers of the Signal Service, cases have occurred in which the railroad times to which their clocks were regulated, differed by ten or twenty minutes from the correct local time which it was supposed they were using. These discrepancies are so exceedingly annoying in minute studies upon thunder-storms, tornadoes, auroras, earthquakes, meteors, &c., that I have not hesitated to take every practicable step toward the attainment of accuracy and uniformity. Accordingly, in the new Instructions to Signal Service Observers, no local times will be recognized, but only the Washington time, as telegraphed from this office. It is very possible that the Washington time so telegraphed will, on some future occasion, be regulated by the 75th meridian, west of Greenwich. In order to promote the distribution of standard time, the Signal Service has, for some years past, had charge of the time-ball at Boston, and I propose to extend this service as far as possible, in accordance with the terms of the accompanying circular letter.

In order to answer numerous questions relative to time-balls, a letter of inquiry has been sent to astronomers having experience on this subject, and this, with their replies, has been embodied in a professional paper which includes a very full description of the Boston time-ball by Sergeant Purssell, in charge of that station.

Judging from expressions of interest in this matter, there seems no doubt but that the country, generally, would welcome any attempt on the part of this service, to distribute standard time signals, in conneetion with its daily weather and river reports; but in the distribution of such signals, over so wide an extent of country, it is important to decide what meridian is to be adopted as the standard.

PERMANENT CORPS.

At the proper time, Congress will be asked to increase the Signal Corps by the permanent addition of a sufficient number of officers to obviate the necessity now existing of calling for permanent details from regiments. The existing plan is very objectionable, since colonels have a plain right to the services of their officers, while officers of regiments, who have served a long time in the Signal Corps, on account of the special character of their work, are indispensable to it, and, from length of service in it, have a tacit right, and have received encouragement to look for permanence in it. Unless this plan is adopted, the duties of the Signal Corps, now so enlarged, cannot be performed in the efficient and acceptable manner imperatively demanded. In addition to this class of officers there are others I deem it my duty to call to your attention. As in all corps of highly a scientific character, it has been found necessary, from the inception of the Signal Corps, to engage in its service civilians of a high order of scientific attainment, and who are known as professors. I find at the head of these Professor Cleveland Abbe, to whom the corps and country are under very great obligations, and it is. recommended that he, with the other civilians now serving, be provided for by law, without any increase of pay over what they now receive, as is done at the National Observatory and in the Coast Survey.

I will also ask authority for the addition of a permanent party of forty men at Fort Myer.

It is believed that the pay now provided for the men of the Signal Corps is ufficient to attract the young graduates f the higher institutions of learning of he country, and an effort is being made o recruit the corps from such sources, with good reason to expect success.

The very great value of the meteorological and other data existing, and rapidly accumulating, in this office, exosed to destruction by fire and the great inconvenience of the present arrangements for the work, spreading as it has done into five different buildings, will make it imperative during the coming year to inaugurate a plan for obtaining a single building which shall be fire-proof, with capacity and arrangement suitable for the purposes of the office of the Chief Signal Officer.

CONCLUSION.

In closing my report, I must again refer to the fact that in addition to the statement of progress during the year, much must appear in each report that has already been noticed in previous years, since similar facts in organization and service will receive similar descriptions. The favorable action of Congress has yearly aided the progress of the Signal Service. The nature of its work makes it deserving of a hold on the esteem and affection of every household.

It is hoped there may be no failure in the appropriation for the Service of the amounts estimated for, which have been carefully and economically considered.

The advancement of the Service has been accompanied by continued and satisfactory success. The popular confidence and support have never been impaired and the scope of its usefulness increases with each year.

THE PRESENT CONDITION AND HOPES OF ARCHITECTURE.

From "The Builder."

If the English lover of the Græco-Roman and Italian columnar style feels surprised at the existence of dissatisfaction with this architecture evinced by the oft-repeated complaint of our want of National style, he must feel infinitely more so on discovering that a similar dissatisfaction with the style exists among the Italians themselves; which is the fact, if the declared persuasion of an eminent critic (Signor Camilla Boito) of the necessity for a new style, and attempt to invent one, together with his being allowed opportunity of embodying the result in important buildings, are to be taken as an indication of the public feeling.

Let us consider what the columnar architecture is, which has come down to us through many hands, and the foreshadowing of which formed the material grandeur of the early and renowned capitals of the world—Nineveh, Babylon, Persepolis — which was the glory of Athens, the magnificence of Rome; and for the embodied relics of which at the revival of art the greatest architects of Italy dug as for hidden treasures. The classical columnar ordinance of the Greeks and Romans I look upon as the essential nucleus or framework of the architecture of the world, for which we can imagine no substitute, and which must have appeared had the temple solemnities of Egyptians and Greeks never required it. It lay, a divine creation, like geometry or analysis, in the womb of chaos, and must of necessity have been called forth by the first imaginative and cultured people. It is, like the mathematics, rather a discovery than an invention of man. It is not occasional and peculiar, but symbolical and universal. Whatever new building material was introduced into architecture, or whatever material becomes dominant, the colonnade will not become obselete. The simple and natural beauty of insulated columns, the magic of peristylar perspective, must ever charm the imagination of the educated and uneducated, the young and the old. The exclusive admirer of the Gothic should remember that that style is a lineal descendant of the Classic, and owes to the Classic its most pleasing features. The most beautiful Gothic cathedrals are those that show most reminiscence of the colonnade or round columns, a dearth of which always produces a harsh, liney appearance.

The same may be said of the Byzantine, Saracenic, and other styles. In fact, in the Greek temple of Corinth were lodged the germs or principles of the whole architecture of the world, as are the rudiments of the future plant in the seed. For this reason it is that in treating of the position and hopes of architecture I confine myself chiefly to classical, and not from any narrowness of view and aim, or lack of sympathy with the other beautiful and interesting, and equally true phase of it.

You meet with the colonnade, or anticipations or reminiscences of it, everywhere—in the Hindoo and Buddhist temples, and cave temples, and in palaces, tombs, and mosques of all Mahommedan lands. Architectural ambition has almost always embodied itself and broken forth in columnar grandeur; as if the beauty and capacity for sublimity of groves of columns had smitten the imagination of every people possessed of one on the earth.

It is absurd to go into raptures over the Parthenon and be, at the same time, indifferent or opposed to the columnar style, because all that charms us in that building belongs to the columnar style, every example of which is susceptible more or less of the beauty and harmony of the Parthenon, which, denuded of its sculpture, remains exquisite architecture, proving it, like female loveliness, independent of the foreign aid of ornament. But the quality of being self-dependent or having need of nothing bears most analogy to the excellence or perfection of the Supreme Being, and therefore most divine. It is an attribute of the style that eminently fits it for the solemn temple, which it will as truthfully form as the gorgeous palace. And if it cannot express so vividly the hopes and aspirations of the Christian as the Gothic, its abstinence from the attempt is to the preservation of beauty in its sacred embodiments, and renders them a truer reflection of that grace of external nature which is the veil of the Eternal Cause, and nearer to the fashion of the shrine which we may suppose He would himself have built to His worship; more likewise in unison with the holy and beautiful breathed from the Lyre of Inspiration.

Let no one suppose the columnar architecture a mere stereotyped formula of three or four columns; for the scope for variation on their capitals alone is infinite. To it belongs the dome in its utmost chasteness and grandeur.

This is the style which certain architects and critics would supersede by some new invention.

The sudden appearance and general introduction of a new style has no precedent in the history of architecture, even among the most artistic nations. We can trace every known style back to its origin and descent from one or more parent styles, generally to two, except the Pelasgic, Egyptian, and Assyrian, their origin being lost in the night of time, and no remains of earlier styles having been found. New styles, it is true, have been evolved spontaneously and slowly by the mingling of two others, and may be again—the growth of similar circumstances; but no style was ever called out of chaos. To reject the columnar ordinance of the Greeks and Romans, and seek for new elements, is as absurd as to reject all that has been wrought out in philology and literature, and go back to Cadmus or to hieroglyphics. He who does so places himself in a worse position than the first nations. He is like a poet by nature, endowed with the highest gifts perhaps,

"The vision and the faculty divine
Yet wanting the accomplishment of verse."

He forgets, or is ignorant, that architectural creation does not consist in calling architectural designs from nothing; that it matters not how much an architect is indebted to other men for his materials, if he combines those materials according to new affinities and "adorns nature with a new thing." Nor need he be surprised if any architectural style which is the child of his own brain, does not find favor, or that it results in something the embodiments of which in buildings it would be flattery to call architecture. He must, indeed, soon discover that his only chance of competing with the past in architecture is to avail himself of the labors of his predecessors, and adopt the columnar ordinance of the Greeks and Romans, or the arcuated system of the Mediævalists.

Than such movements and the criticism, English or Italian, that leads to them, nothing can be more mischievous; for the faith of the student in the truth and capability of the style, which it is calculated to unsettle, is essential to his progress; and architectural students are in vain exhorted to diligence and enthusiasm in the pursuit of their art when they are left in doubt by conflicting criticism what phase of it to pursue, or whether any phase of it is worthy of their acceptance. Faith is as essential in art as it is in religion; for "if the trumpet give an uncertain sound, who shall prepare himself to the battle."

But for this criticism there would be little need of inciting to zeal in the fascinating study of architecture. As in religion, unshaken faith would be followed by love in the breast of the student for one or another of the styles of the day that solicit his attention, according to his natural or acquired predilection.

Though, on the other hand, there are not wanting critics who, from dissatisfaction with present practice, or late efforts at originality, counsel the mere adapting the old productions of this style to modern purposes, and even go so far as to suggest copying, I will not suppose that the descendants of the ancient Greeks and Romans—men with more or less of the blood of Phidias and Praxiteles in their veins, for such are the modern Italians—are ignorant of the right use of architectural examples to the architect, or unable to grasp the true principles of their combination. I cannot but suppose that Italy contains hosts of men with sufficient imagination—the vital quality in all art and artists—to fuse into other harmonious examples the same elements from which those elder buildings were composed; in other words, of making the same use of the elements so abundantly placed at their command that Sansovino and Palladio made; which does not need a succession of eminently gifted men. Men of ordinary abilities would suffice if they have any reasonable depth of artistic feeling, which gives a power and insight to the intellect it would not otherwise possess.

Ancient examples are to be neither copied nor adapted; both practices are unworthy of an architect. Those who recommend them forget, or are ignorant of the epochal, local, and ethnographic nature of architecture—the relation it bears to its own age and country. Ancient buildings cannot be examples for all times and places. They are to be mentally dissolved and recombined into other forms—decomposed and recomposed.

Nothing is more natural than for the Italians to adopt this columnar ordinance, for it is their own rightful property—the bequest of their forefathers. Italian architecture is not strictly a revival or resurrection of the Græco-Roman architecture, as it is generally supposed to be, for that style never died at Rome, which, owing chiefly perhaps to the sacred character of the Pontiffs, preserved in a greater degree than any other city the traces of ancient civilization. The night, it has been said, which descended upon her was the night of an Arctic summer. The dawn began to reappear ere the last reflection of the preceding sunset had faded from the horizon. A stream, narrow indeed, but pure, of that architecture came down embodied in the Christian basilicas at Rome, which are not Romanesque, but Roman, whence it issued into all the countries of Europe. Certainly it was not revived in the sense in which Greek literature or painting or sculpture was revived. Greek literature had been lost to Europe for centuries, and survived only among the Saracens and Eastern Romans, from whom it was first recovered in the thirteenth century. Greek painting had been lost till recovered by Cimabué and Giotto from the Byzantine school; so had sculpture, of which Pisano was the modern restorer. But Græco-Roman architecture, alive from classic times, was present in all its beauty at the capital of the world when it was wanted, and, blended with Italian Romanesque, contributed to the inspiration of the Venetian, Roman, Florentine, and other varieties of the Italian in the sixteenth century.

I can imagine nothing more natural or droper than the resumption of the ancient architecture by the Italians, nor than the general course which it took in Italy in the fifteenth and sixteenth centuries. Let us glance at its history. It is probable that Brunelleschi was the first to infuse a purely antique spirit into his works, among which may be cited the cupola of the cathedral of Florence, the erection of which opened the way to the greatest architectural enterprises of modern Europe, the Church of the Holy Ghost, and the Pitti Palace in the same city. He was followed by L. B. Alberti, who emulated the achievements of his predecessors, and in some respects excelled them. The churches of St. San Francesco at Rimini, and of St. Andrea at Mantua, with the Palace Rucellai at Florence, are among the best of his works. Michelozzo, a scholar of Brunelleschi's, and other Florentine architects, followed Alberti, and were seconded in developing and applying the style by Bramante, who had practised in the former one. The Belvedere Court of the Vatican, the Court of the Loggia, and the Sora Palace at Rome, are specimens of his graceful manner. Peruzzi showed greater freedom in the use of his materials, as witness the palaces Farnesina and Massimi at Rome, and was seconded by Antonio Sangallo and by Raffaelle, in whose hands and those of Michelangelo, Vignola, San Michele, Sansovino, Palladio, and others, the style of ancient Rome was restored in all its grace and grandeur, and so expanded by additional elements, in its application to new uses, as to be rendered a distinct style, and in some respects a more consistent one than its antique parent or prototype.

No trail of the serpent seems to have been descried on it by any one of the architects just named, and many of them are men of strong religious feeling. They probably remembered that it had been in the service of Christianity, in the Basilicas before mentioned, since the time of Constantine the Great, long enough to atone for its guilt, if it had incurred any, in the service of a false religion; if, indeed, they did not feel that there is a holiness in real architecture, as in all true art, which no alliance with heathenism or anything else could take away. Such was the course of architecture in Italy, and the career of its most eminent professors—the greatest architects, painters, and sculptors of the most accomplished age of the world since that of Pericles.

Now, if the human heart and imagination is the immediate fountain of all poetry and art, it is exceedingly absurd to suppose that the artistic instincts of such men, including one I have not yet named, Leonardo da Vinci, who, being an architect, was also concerned in the movement—a painter, sculptor, poet, the greatest intellect of the fifteenth century, and seemingly of universal and superhuman knowledge—should have betrayed them into a wrong path—a path in which originality and progress was impossible—and that another galaxy of great artists should have blindly followed them. I conceive that such men would have gone right by the mere force of their imaginations, and have been more likely to make a stride in the right direction than to slide into a wrong one. I conceive that such men as Da Vinci, Michelangelo, and Raffaelle, whose names are almost synonymous with beauty and sublimity—who had grasped the whole realm of design, and were almost the inventors of chiaroscuro in painting—would leave examples of a proper union between the three arts, and advance the style in every respect as no mere architect could. We should remember that artists such as they—of the highest order that ever appeared on earth—have always uniform, well-balanced minds, with judgments commensurate with imagination. If it be argued that true architecture is that on which its authors have impressed the leading thought of the age, I answer, the revival of the productions of classic antiquity was the great thought of that age.

But this style is greater than its examples; and its highest reach of monumental grandeur or utmost possibility is not to be judged by its most important embodiment—I mean, of course, that most costly and ambitious structure ever reared to the honor of Christ—St. Peter's Church at Rome—which, from some cause or other, does justice neither to the capabilities of the style nor the genius of the great architects employed on it, The exterior, of which alone I am speaking, has not a single detached column about it, and is, therefore, deficient in relief.

This church has been overpraised both by Byron and Lamartine, the latter more extravagantly when he says that in St. Peter's Church Michelangelo has clothed the idea of God with all the beauty of which it was capable, which is not true. The front of it was susceptible of such treatment by means of colonnades as would have rendered it infinitely more beautiful. Never was the homely proverb, "Too many cooks will spoil the broth," more strikingly verified than in the design of the Pontifical Church of St. Peter. The least eminent of the architects employed on it ought to have produced a superior principal façade, which lacks those mighty and vigorous masses of shadow without which, as Ruskin justly remarks, no building can be truly great.

Great mistakes, I grant, may be attributed to many of the leaders of the movement, and to none more than to him whose name has become identified with Italian architecture—Palladio, who, it is certain, has been over-estimated by many eminent critics, as Quatremère de Quincy, Hope, Beckford, and, strange to say, by the great poet and philosopher, Goethe, who represents him as ever seeking to embody some "great image which he has carried in his soul," a scarcely correct notion of architectural generation. He too often forgot that the beautiful in architecture springs out of the useful, having left instances among his works of unbordered windows, and of the columnar order constituting the whole of the architecture, which could, therefore, be separated from the building, though the better principle had been exemplified in the Florentine school. Palladio, however, oftener pursued architecture in the right spirit, and has left works, in the true sense of the word, original. He had no notion of merely reproducing Roman buildings, nor even adapting them to his purposes, but strove to mould the antique elements into accordance with his own ideas. He seems to have begun his career with the persuasion that the style would stoop to the humblest purposes of life, and that in extending it to such he was only continuing the application of their architecture begun by the ancients themselves. His predecessors probably considered it as fitted only for churches, palaces, and public buildings; but Palladio's varied works at once proved that its applications were unlimited.

But be his faults or mistakes what they may, they are no reproach to the style which was practised in his time, the productions of which, in not a few instances, while they are not unlike any former works, and therefore original, are amongst the most successful structures ever reared for harmony and beauty of form, and refinement and elegance of detail; being the issue of a fruitful imagination under the guidance of a pure and sound judgment.

Brighter and more enchanting forms than any that have yet appeared may be embodied by it, brought from among the golden visions that lie mirrored in the fairyland of the imagination; especially of the gayer and more aërial kinds, which will be admitted by him whose eye, bodily or mentally, has ranged over the creations of a style which is an offshoot of it—the Saracenic—in various countries of the East, more especially the exquisitely lovely scenes of fairy splendour in Hindostan, which are frequently aided in their designed character by a material of such purity and brilliancy that the whole resembles a flood of moonlight.

More artistic and higher combinations of Greek and Roman elements than Palladio or his predecessors or followers thought of are possible, and, what is more, are really called for by utility in some of the highest class of works. The great defect of the trabeated system is, that it is only fit to form the façade of a building to be entered singly, or in single file, and will not form the lofty and broad entrance required by a palace, or church, for processions, without injury to its beauty; and while the colonnade is necessary to the highest grandeur, the arcade is essential to a great entrance door or gateway. It gives the largest single opening—an opening as broad and high as can be required.

But I believe the two principles can be combined in the formation of a grand entrance consistent with artistic harmony and unity; that is to say, two colonnades may, with some careful management, be combined by means of a connecting archivolt springing from entablature to entablature, into one great and harmonious feature, embracing a central entrance, which may be as great and lofty as could be desired. The side intercolumnar spaces would be subsidiary entrances, and highly useful and pertinent; or, where not required for entrances, would form framework for sculpture. The breadth of entrance thus secured seems highly desirable in any public building, whether public processions are to be provided for or not; and the mode of obtaining it here suggested is worthy of consideration for its increase of combined fitness and beauty. It would be a new kind of coalition between the Greek and Roman or Romanesque styles.

The Italian style as it spread from Florence, where it rose, to Rome and Naples on the south, and to Venice, Genoa, and Milan on the north, accommodated itself to the natural, political, and social peculiarities of each city; most notably to those of the sea-girt and sea-intersected Venice, and so became the chief ornament of that gem of cities. It showed it could breathe a still more northern air, that of England, wherein a few works could be found that, for purity, harmony, and appropriateness, will compare with any of a corresponding class in Italy; along with abundant proof that no elements will so satisfactorily weave into the continuous houses or shops we require in our streets, with regard both to convenience and beauty. Indeed, its merit and value lie not in its sageness and beauty only, but in its organic vitality and possession within itself of the principle of future expansion and application to all the multiform and accumulating demands of human life. It will as truthfully form the features rendered needful by rain and wind and cold as those required by sunshine and heat; in other words, it is a Northern as well as a Southern style.

It will, doubtless, form in perfection every species of public and private edifice called for by the various institutions of every country of Europe, including engineering buildings, bridges, viaducts, &c, along with strictly architectural ones, without sullying its classic purity, but rendering them musical as Apollo's lute; for those columnar elements are susceptive of the utmost grace and refinement of which structural art is capable.

Such failures as the exterior of the British Museum are no disparagement of the style, for that is a magnificent display of its elements, which, owing to timidity or want of imagination in the architect, were not worked up into a design. It is not answerable for that, nor for another remarkable instance of undigested material, which, in justice to architecture, should be pointed to, viz., the new Houses of Parliament at Vienna, a view of which was given some four years ago in the *Builder*, and now, I presume, approaching completion; which is nothing more than a number of decorated blocks of building in mechanical conjunction, which, though forming a magnificent architectural group, have no claim to be considered a work of art.

Nor are those modern buildings, which are externally reproductions of the Greek peripteral temple, such as the Town Hall at Birmingham, the Church of the Madeleine and the Bourse at Paris, the Walhalla at Bavaria, to be considered as anything but libels on the character and resources of the style, which is capable of infinite variety on the Greek type, and greater display of columnar richness and grandeur. The periptery, unless redeemed by Parthenon-like perfection of line, by variation of capitals in the same façade, and high-class sculpture in the pediments and friezes, is a monotonous spectacle. Klenze in the Walhalla could have produced a national temple that would, in point of composition, have been an advance upon it.

What in each country this style requires is to be made as much as possible to form, not adorn merely, windows, doors, porches, chimneys, and other features required by the climate, in emulation of the Gothic, which grew up and around—identified itself with—essential features, as in the window, which was the most useful feature, and became the most beautiful, the useful and beautiful growing up in conjunction; which must be always the most pleasing, like that rarity —a virtuous mind in a beauteous body.

As to the chimney, it seems a providential provision for relieving the sky line, and giving intimation without of the home life within.

The so-called Queen Anne movement, in search of greater picturesqueness, seems to me to be uncalled for. Holland is useful to feed the imagination of the architect, which must ever be indebted to reminiscence—a fact the ancients meant to indicate by representing the Muses as the daughters of Memory. Inspection of the picturesque buildings of Holland is calculated to make his own mind more prolific. They are seed cast therein to bear fruit in his own works. But with the highest reverence for the art genius of the Dutch of the seventeenth century (most brilliantly manifested, however, in painting), I think it is unworthy of English architects to introduce and set up here a style from Holland. It is, to say the least, going to the huckster's shop instead of the warehouse for our provisions.

If we are as truthful and independent in our treatment of the columnar architecture, in acclimatizing and nationalizing it, as were the Dutch architects, and withal pay due attention to the securing a good and lively outline, and light and shade in designing, and are careful ever to make a beauty of necessity, we shall be sufficiently picturesque. Time and weather and accidents are agents in the production of that extreme degree of picturesqueness which the landscape painter delights in; and their effects are not to be anticipated by the architect.

When I contemplate the beauty and capacity of the style in question, and of the styles descended from our forefathers in their respective embodiments—the result of the highest efforts of the wisest nations in the way of architecture, forming a mine of elements such as neither Greek nor Roman ever knew, and put into the hands of all by means of engraving and photography, I feel more disposed to exclaim, in the words of the Psalmist, "The lines have fallen to us in pleasant places, and we have a goodly heritage," than to complain of the want of a national style. For if these are not our national styles whose are they? A question history is best able and has most right to settle, and she intimates, I think clearly, that in working in an adapted or modified Italian style we are truly succeeding and following the great nations that have preceded us in civilization—Egyptian, Etruscan, Greek, ancient and modern, Roman, Venetian, Pisan, and Florentine—in the way we should go—the providential way, with increased and accumulating means and opportunities of arriving at successful issues. Our difficulty seems to me to be not in having no national style, but in having two national styles—the style we inherit from classic antiquity along with its civilization, and that bequeathed by our forefathers—a style to which many hearts cling, and not without cause. We have two phases of architecture, so beautiful that we cannot turn our backs upon either, and may say, in the words of Gay's "Beggars' Opera"—

> "How happy could I be with either,
> Were t'other dear charmer away!"

and I question whether any former nation would not have felt and acted in a like manner.

If the Gothic would borrow a little more of Greek refinement from her Oriental sister, the Byzantine style, of which she is highly susceptible, and fully recognize the change in the world and in her own circumstances since she fell asleep in the sixteenth century; and if the classic at the same time were fully nationalized, they would assimilate so far that there would be but little discord in our towns arising from the pursuit of both.

Whether they would or not, neither Gothic nor Classic can ever be abandoned in favor of a new style; for no new style will ever be invented or generally followed. We had better, therefore, accept that fact, and pursue the styles we have, which, indeed, seems the providential course. Each style, however, should have its separate followers, as no man can with heart and soul follow both; and the student should be taught to make choice of one or the other, which would be most favorable to his growth in artistic feeling and power. It was, therefore, wise in the Royal Academy Professor in his recent lecture to discourage the following a plurality of styles. Inigo Jones was, doubtless, right in appending a Corinthian portico to old St. Paul's cathedral. He could put some feeling into that, but he could probably have put none into a Gothic porch, and a living dog is obviously better than a dead lion.

I conceive of architecture, like the graceful figure of her on the tomb of the Italian architect Sada, engraved in the *Builder* not long ago, as flourishing in the bloom of an immortal youth and beauty—for such the rose of juvenility must intimate on the brow, pensive though it be, of a lady who, if her first advent on earth was in Egypt, and the sanctuary of Karnach was her firstborn, must be over 4,000 years old. I grant that she has betrayed great eccentricities within the last century, not only in England and the North, but in Italy, the birthplace of her most illustrious modern followers. But I strongly suspect that her aberrations are in a great measure owing to the conflicting opinions and advice of her councillors (the critics), whose utterances have been, in too many instances, merely empirical, and too seldom based on the spiritual and emotional nature of architecture and art. Instead of trying to breathe into her some sparks of her ancient fire, by reminding her of her glorious antecedents and achievements, and especially of her labors of love in ancient Greece and Mediæval Europe, through which she has helped the cause of civilization in the world, and even exalted the idea of religion, they have of late been prophesying evil against her, insinuating that she is in a decline, and all but defunct; one, otherwise an eloquent and judicious critic, even talking of mourning in sackcloth and ashes over her degradation. A glance over the chart of her history will show that she is, like ourselves to a great extent, the creature of circumstances—the sport of accident; and if so, surely no circumstance, no accident, can be more injurious to her than such conduct on the part of her friends, concerning whom she might well, with the ancient Roman, cry out to the Gods, "Oh, save me from my friends!"

What she has once done she can do again. The aliment on which she lives is as nourishing and the fountains of her inspirations are as lofty as ever they were, and more unfailing. Of a soul-born, spiritual substance, she is necessarily indestructible, and exempt from the common lot of obsoleteness:—

> "Age cannot wither her, nor custom stale
> Her infinite variety."

Like her sisters, Poetry, Painting, and Music, she has fresh fields and pastures new and delightful for ever stretching out before her, through which she may

> "Still walk in beauty like the night
> Of cloudless climes and starry skies."

But I have long been of opinion that her gait and mien would be more majestic if she were not so much perplexed with matters which do not properly belong to her, and which might very well be intrusted to another and more material agent, called Practical Building or Construction, who would be held responsible for the faithful and durable embodiment of her images of beauty. She should be on intimate terms with, nay wedded to, Constructive Science, and her conceptions should be the fruit of the union; but beyond the full mental development of every part of her offspring as to form and hue in all their minutiæ, she should not be expected to operate. All the rest ought to be left to her deputy, or subordinate, Practical Building, educated expressly for the post, who should govern and direct his invaluable servants —Masonry, Bricklaying, Carpentry, Joinery, Plumbing, &c., and become answerable for their honest service. I do not mean that she (Architecture) should shirk any mind or heart work whatsoever, but simply relieve herself of all that is merely mechanical, and that could be as well or better done by another, and reserve her strength for higher work.

I know nothing more that is wanting beyond what I have directly or indirectly pointed out to render her winter of discontent a glorious summer but sincere and earnest followers who, like Michelangelo, would work for the love they bore to her, and not merely for the gold they could wring from her. Some gold they must have, and some gold she will doubtless give them, but the "accursed thirst of gold," as the prince of Latin poets calls it, must not be their inspiration. It is not too much to say, "We cannot serve her and Mammon," a truth which it is important for those who have her interest at heart, and are anxious to remove all stumbling-blocks from her path, to bear in mind. A community of her true followers, wheresoever born, bound together by sincere attachment to her for her own sake, would constitute the true modern Freemasonry, and be a worthy successor to the Mediæval; the proper successors or continuators of the Freemasons being surely architects and skilled and scientific builders, architectural sculptors and carvers, and even earnest foremen and workmen, rather than the miscellaneous fraternity (miscellaneous as regards individual professions) that now bear the name.

That such a community of various ranks of earnest men, each pledged and incited by every high consideration to the service of their beautiful mistress, through evil report and through good, nothing, I think, would be better calculated to meet the present exigency, and awaken in the profession, or at least in the breasts of all susceptible of it, some sparks of the pure religious - and - art spirit under which the Mediæval Freemasons worked; while the achievements of the Freemasons, and Greeks, and Italians—that is architecture in its highest examples and possibilities —would be likely to seize upon and inflame their imagination, and become an ideal standard of aspiration. Such an institution would like chivalry, have a purifying and elevating influence on the character of each member.

Within such an institution I can imagine the workmen sympathizing in the emotions of the architect, and having an æsthetic part in the adornment of his works.

THE PHYSIOLOGICAL EFFECTS OF COMPRESSED AIR.

By C. M. WOODWARD.

From Advance Sheets of "History of the St. Louis Bridge."

VERY little was known of the peculiar effects of compressed air upon men when the sinking of the East Pier of the St. Louis Bridge began. The observations of European engineers where it had been used were generally limited to the effect upon the human ear. In 1852, Mr. J. Hughes, assistant engineer at the Rochester Bridge, England, noted that men at work in compressed air had "a remarkable increase of appetite for food." Respiration, he says, was "slightly affected," and when the transit of the air-lock was rapidly made, there was some complaint of headache. The greatest depth under water was 61 feet.

In 1861, Mr. Robert P. Brereton, one of the assistants of Mr. Brunel at the construction of the center pier of the Royal Albert Bridge at Saltash, England, stated before the Institution of Civil Engineers some of their experiences. The maximum air-pressure was 40 pounds above the normal; usually the pressure was much less, as the water in the main cylinder was kept down by pumps. Mr. Brereton said that at first his men worked too long at a time, and on coming out they were slightly paralyzed, but in two or three days they quite recovered. With three-hour shifts the men could remain at work for several months consecutively. (Brunel was about two years in establishing his pier.)

The eminent engineer John Hawkshaw said that at the Londonderry Bridge, "where 75 feet pressure was experienced, there *had been some casualties.*" One of the effects produced by the air-pressure was that the joints of some of the less robust men began to swell.*

In 1865, Dr. A. Magnus, of Konigsberg, published the result of his observation upon the effects of compressed air in the caisson of the bridge pier at that point.†

"It has been shown in former works of this kind (at the mines of Douchy, for example) that the human organism may endure a pressure of four atmospheres without harm, but that it frequently happens that sickness is caused by a rapid *diminution* of *pressure*. So far as I know," he continues, "there are no German publications about this matter, though certain Frenchmen speak of them." The rules he gives have reference only to the ear, when entering the air-chamber.

In like manner, all who had written on

* Proceedings Inst. Civ. Eng. Great Britain, Vol. XXI.

† "Schriften der physikalisch-okonomischen Gesellschaft." VI. Jahrg., 1865.

the subject had assumed, from the comparative immunity with which men worked under two, and even three atmospheres, that no harm could arise from four or five atmospheres.

Reference has been made in a previous chapter to the visit of Mr. Eads to the bridge-building at Vichy, in 1869. Mr. Audernt, the resident engineer, had put down forty piers by the method of compressed air, but his deepest had been only 75 feet below the surface of the river (the Po at Placenza); but neither he nor Mr. Moreaux (the "builder of a thousand bridges") could give any definite opinion as to the practicability of working men at a depth such as the East Pier of the St. Louis Bridge would reach. In England, Mr. Eads conferred very fully with Mr. Brereton. It is probable, however, that his own diving-bell experience made him the best judge of the effects of air-pressure, and yet even he had no adequate idea of the peculiar results actually experienced. As he himself said, no similar work having penetrated to so great a depth, he was left without any benefit from the experience of others, either in guarding against any injurious effects of the great pressure upon the workmen and engineers subjected to it, or in relieving those affected by it.

With this brief introduction, I proceed to give as full account of all matters relating to compressed air during the building of the St. Louis Bridge as my space will permit.

Until the cutting-edge of the caisson of the East Pier was nearly sixty feet below the surface of the river, there was no serious drawback to working four, or even six consecutive hours in the air-chamber. The men worked eight hours consecutively, coming up, however, to lunch at the end of four hours, till the caisson was down 42½ feet. Then, one of the foremen being sick, it seemed best to change the day's work to two watches of four hours each, with a rest of eight hours between. This scheme was followed till February 5, when, the immersion being 65 feet, a day's work was changed to six hours, consisting of three watches of two hours each, with two-hour rests.

The first effect noted upon the men was an occasional muscular paralysis of the lower limbs. This was rarely accompanied with pain, and usually passed off in a day or two. As the depth of the caisson increased beyond 60 feet, the paralysis became more difficult to subdue. In some cases the arms were involved, and in some the sphincter muscles and the bowels. In the severer cases the patients also suffered much pain in the joints and in the region of the stomach. Many of those affected suffered no pain whatever.

So long as the affection was painless, it was not regarded as a very serious matter. A workman walking about with difficult step and a slight stoop was at first regarded as a fit object for jokes, and cases of paralysis and cramp soon became popularly known by the name of "Grecian bend." In some cases there was paralysis of the nerves of sensation alone. The numbness generally extended over one or both legs, although it occasionally applied to the arms and face.

The common remedy was the rubbing of the affected parts with oil or liniment of some kind. A certain "Abolition Oil" gained great popularity: according to Col. Roberts, it "worked like a charm,"

In cases of entire or partial paralysis of the limbs, a battery was frequently used, but the records show that the remedy was thought of little value. A more efficient means for relieving pain was the warm bath, and it was repeatedly used for the earlier severe cases. Subsequently, Dr. Jaminet forbade its use, though it was a first remedy at the City Hospital.

A fancied safeguard was the use of galvanic bands or armor. At first, in the opinion of the superintendent, the foremen, and the men, the armor gave remarkable immunity, and all the air-chamber men of the East Pier were provided with it at the company's expense. The bands were made of alternate scales of zinc and silver, and were worn around the wrists, arms, ankles, waist, and also under the soles of the feet.

As the pier descended into the sand, the distance from the top of the pier down the winding stairs to the air-lock increased as well. A depth of 70 feet made it necessary for each watch on its exit from the air-chamber to climb about one hundred and forty steps. The men were instructed to rest frequently on their way, but the request was generally disregarded. The fatigue of the ascent added not a little to the distress and prostration of those affected with cramp.

It was noticed that to one with cramps it was often a relief to return to the air-chamber.

When the immersion was 65 feet, a man just leaving the air-lock became unable to ascend the stairs. On the 15th of February, immersion 67 feet, a man suffering greatly in his limbs and back was sent to the City Hospital. From this time forward severe cases of cramps and paralysis were frequent, and several cases were sent to the hospital. The superintendent noted the fact that the sick were often thinly clad and poorly fed. One man became unconscious, and did not speak for three hours. All that they could do for him was done. He was stripped, rubbed, and wrapped in warm blankets. Mr. McComas says (in his diary) that the poor fellow came to his work with no stockings (the weather was cold), and that his clothing was very thin.

A great majority of the cases were among the new hands. In marked contrast with the number of men who were attacked at the end of their first trial was Keith, a sub-foreman. On February 20, when the immersion was 81 feet, the foreman of his relief being sick, Keith remained in the air-chamber ten hours out of twelve, and suffered no harm. Occasionally the old hands suffered, but the severe cases were new men. On February 26, nine men were attacked at once, one an old hand; none, however, seriously.

On the 28th of February the caisson reached the rock. Immersion, 93½ feet; pressure in the air-chamber, 44 pounds above the normal. The two foremen had been very active for a day or two, in their zeal to "land the caisson," and, as a consequence, while all others were rejoicing over the triumph they were groaning with aches, which did not yield to the ordinary applications. "All remedies fail," wrote the superintendent, at 5.40; "Shrieves is suffering severely." At 6.40 *he was well and out.*

For a few days the force in the air-chamber was small. Most of the workmen were affected. "It seems impossible," wrote Mr. McComas, "to keep a force up." He determined to shorten his watches to one hour. The next day the gangs were relieved every hour. There was no complaint, but the men evidently disliked being called up so often, and dreaded so many ascents of those winding stairs—100 feet high. The following day they resumed the two-hour watches. They were concreting now, and the work was hard. The gangs were small and carefully watched. Soon Mr. McComas concluded to have them work only by day—four gangs, two on and two off; three watches of two hours. The night gangs had suffered most, the explanation being that the men did not rest properly by day.

There were only a few cases from then till March 19; then they were startled. This "log" entry of Mr. McComas tells the whole story: "James Riley died today at 10.15 A.M. Verdict of the jury, 'apoplexy.' He had worked only two hours in the air-chamber. Came up feeling very well as he said to one of his friends. In fifteen minutes afterwards he gasped and fell over, and was dead in a few minutes. I was fearful it would have a bad influence on the men, but they did not appear to mind it in the least." This was the first death, but another of the men died at the hospital the same day. During the next few days several very severe cases were sent to the hospital, and three more deaths occurred—two on one day. On March 28, a man applied for work in the air-chamber, whom the superintendent, for some reason, refused to take. A little urging resulted in the man's putting on the armor and working two hours. Fifteen minutes after coming out he was dead. Verdict, "apoplexy," as before.

It was evident that more stringent regulations were necessary to check both the number and the severity of the cases. Dr. A. Jaminet, a regular practitioner in the city, and Mr. Eads' family physician, was employed to take charge of all the men at work in the air chamber, and to establish such regulations as in his judgment the well-being of the men demanded. Dr. Jaminet took charge March 31. A floating hospital was at once fitted up on a boat lying just below the pier. Besides ordinary accommodations, berths were fitted up in which workmen could lie down during their hours of rest.

Dr. Jaminet had been a frequent visitor to the air-chamber, and had himself felt the peculiar effects of compressed air. He had been much interested in testing the familiar law regulating the boiling-point of liquids when under pressure, and in noting the effect of the compressed air upon himself and those who entered the caisson with him.

Dr. Jaminet had noted the men as they came from the air-chamber. Their appearance was palid and cold. In some the pulse was quick, varying from ninety-five to one hundred and ten, but somewhat weak; with others it was as low as sixty. Without exception, the workmen complained of fatigue.

Dr. Jaminet observed that the pulse always quickened on entering the air-chamber, though it soon fell to the normal pitch, and even lower, in the course of a watch.

On one occasion, the pressure being 32½ pounds more than an atmosphere, he recorded the pulse of himself and five other visitors as follows: Before entering, 81, 78, 78, 79, 79, 80. Temperature, 56° of external air. They were ten minutes in the air-lock. At the end of six minutes their pulses were 100, 88, 98, 86, 95, 90. Thermometer, 62°. Temperature in air-chamber, 48°. In twenty minutes all felt a marked exhilaration. At the end of two hours their pulses were 68, 70, 71, 69, 70, 72. Their chests expanded during inspiration normally. They spent five and a half minutes in the air lock on their return, and they felt very cold. Thermometer fell to 37° in four minutes. Before ascending stairs, pulses stood 69, 70, 69, 71, 68, 72; after climbing the stairs, 106, 104, 92, 94, 102, 99.

On another occasion, Dr. Jaminet, three strangers, and two workmen entered together. Pressure, 37½ pounds. Depth, 81 feet. The pulse record was as follows:

Before entering..........	81	75	76	80	76	82
On entering chamber.....	97	77	77	92	88	90
At end of two hours.....	64	70	67	69	68	68
On reaching top of pier...	104	90	90	100	94	96

In the air chamber, the number of respirations increased from eighteen to twenty-one per minute, and for a time at least there was a feeling of exhilaration. The workmen, without exception, sweat profusely throughout their stay in the air-chamber, though the thermometer was often below 60°.

The air-lock was, as a rule, excessively warm when the pressure was increasing, and exceedingly cold when the pressure was diminishing.

Dr. Jaminet always complained of cold in the air-lock, returning, and severe epigastric pain about ten minutes after coming out. On the day the caisson touched the rock—pressure, 45 pounds—he remained in the air-chamber two hours and three-quarters. While in the air-chamber he felt well. In the air lock, on his way out, he was conscious of a great loss of heat, and a violent pain in his head. The air was escaping very rapidly. (The chief engineer was with him in the lock, and, as was usual with him, the discharge-cock was wide open.) At Dr. Jaminet's request, the escape of air was stopped a moment; the time spent in the lock was, however, *but three and one half minutes.*

With difficulty the doctor climbed the stairs. His pulse was 110; he was suffering severe epigastric pain, and his strength was nearly gone. He went directly ashore on the first boat. With great exertion he managed to walk from the boat to his buggy, not one hundred yards away, and clamber in. He was able to drive to his house, half a mile distant, and stagger into his office, where in a few minutes he became paralyzed. For some time he could not speak, but he retained his consciousness. Gradually he gained command of himself, but his sufferings were intense, and for three or four hours he considered his life in extreme danger. It was over twelve hours before he began to move his legs. A little later he was able to walk, but he was feeble for some days.

Dr. Jaminet made several careful investigations upon the amount and character of the waste of the human system while in the air-chamber. He found that, invariably, an abnormally large amount of urine was secreted, and that it contained unusually large amounts of urea.* It was found that the men had been accustomed to pass very rapidly through the air-lock, particularly when a "green hand" was present. This harmless fun, as it was thought, often cost the poor fellow a great deal of pain and terror, and sometimes very serious injury. Dr. Jaminet instructed the lock-tender to increase the air-pressure no faster than three pounds per minute, and to dimin-

* He estimated the amount of urine secreted during the twelve hours from 7 A.M. to 7 P.M. as, on the average, twenty-eight or thirty ounces per man, and the quantity of urea was "far in excess of the normal quantity found in the urine of a healthy laboring man, when working in the normal atmosphere." The men drank water freely.

ish it no faster than six pounds per minute.

Prior to March 31, the men had been at liberty to spend their "off" hours as they pleased, provided they promptly answered the whistle-call for their watch. The doctor now required them to lie down in the berths provided for that purpose, for at least one hour, immediately on coming up. The intervals for rest and food between the working watches (which last had been three in number and two hours each) were increased to three hours. Each man was also subject to a rigid physical examination; all old hands deemed unsuited to the work were discharged and unpromising applicants were rejected.

Under the new *regime* things promised well. At first the men were on a strike, demanding $5 a day and only four hours' work (they had been receiving $4 for a day of six hours); so there was little work in the air-chamber for some days. April 4, a new man was slightly affected; he was at work again in two days. The next day a sub-foreman (Lyon) was taken seriously ill.* Two other cases occurring in quick succession, a day's work was reduced to two watches of two hours, with a rest of four hours between.

This did not appear to mend matters much. The doctor reports that the men refused to obey orders as to the hours of rest. As soon as their second watch was over they hurried ashore, "and instead of going home to keep quiet and rest, the most of them were wasting their time in bar-rooms, or other places unfit for any man employed in such exhausting work." This strong statement shows that at times his patience was sorely tried.

On the 8th, a man whom the doctor had once rejected came with a friend, and entered the air-chamber without the doctor's knowledge. At the end of the second watch he was taken very badly with cramps and paralysis, and it was months before he fully recovered. Five more cases occurred at the East Pier up to the morning of the 13th of April, when, owing to the flooding of the top of the pier, the concreting in the air-chamber was discontinued. Only one of these cases was serious. The man was badly paralyzed and broken down. After lingering about a year, he died.

The pressure of the East Pier for several days had been 50 pounds. At the West Pier, which was now on the rock, concreting was also going on under an air-pressure of 40 pounds. A very bad case had occurred at the latter pier on the 12th. The pressure being less than at the East Pier, there was thought to be little danger, and the doctor had confined his attention chiefly to the deeper pier. The men had been working six hours per day, in three watches. A few cases had been sent to the floating hospital, but they were slight. The case on the 12th, however, resulted in death. The man was really unfit to be there. He had been a hard drinker for the last year, though he declared he was sober the day he went into the air-chamber. He worked but two hours. This *was the only death* resulting from work at the West Pier.

After the 13th, the number of men at work in the caisson of the West Pier was about one hundred. The day's work was reduced to two watches of two hours each. During the next fifteen days there were fourteen cases of cramps and paralysis. Two or three only were serious, and all recovered. Dr. Jaminet asserts that none of these men had been examined by him, having been employed before he gave his special attention to the West Pier.

A boy had been smuggled in by a friend, and was taken sick the first day. The next day the doctor sent him home, with the injunction not to return; but he came back two days after, and entered the caisson again. After the first watch he was attacked again, and did not recover for a month. On each occasion he was insensible when carried to the hospital. He was twenty years old, and very slightly built.

The air pumped into the caisson was of course very much heated by the work of compression, and the cylinders of the air-pumps and the pipes were kept covered with water as much as possible, in order to keep the temperature down. For some reason, perhaps the temperature of the external air, the air in the

* This man was very sick for three months, and for a long time suffered partial paralysis; and though now (1881) in fair health, he is still lame, and in some of his organs he still feels the effects of his paralysis. For years he had little or no muscular control of the sphincters of the rectum and bladder. At last accounts, however, he was greatly improved, and considered himself nearly well. His joints are unusually sensitive to changes of temperature and barometric pressure.

caisson of the West Pier during two days in April was warmer by some 16° than usual. A corresponding increase of course took place in the temperature within the air-lock, where the thermometer reached as high as 90°.

The doctor was greatly concerned about the effect of this temperature, and in order to keep it down he had an ice-box placed over the supply-pipe.

Notwithstanding the doctor's vigilance and care, cases of cramps and paralysis were of almost daily occurrence. Satisfactory results were obtained only when the following rules were rigidly enforced: 1. The watches were reduced to one hour each, three in number, alternating with long rests of three hours. 2. The men were kept at the pier all day; were required to bring their dinner, and whenever absent for a day they were re-examined before returning to the air-chamber. 3. The men were required to lie down and keep quiet for at least thirty minutes after each watch. Some hot beef-tea was given to each man at dinner.

No new cases occurred for ten days. Meanwhile the submarine work of the West Pier was finished.

On the 11th of May, work was resumed at the East Pier. Men worked three watches of one hour each, distributed over twelve hours. Pressure, 49 pounds. On the first day there was one case, which resulted in speedy death. The victim had worked three months at the other pier, and had suffered no inconvenience. He was on duty from 8 till 9 o'clock, and felt well after coming up. As he had neglected to bring his dinner, he was allowed to go ashore at 11.30 to get a meal. He, however, got nothing to eat, but drank in a saloon. He returned just before 1 o'clock, and worked from 1 till 2. On leaving the air-chamber he, in common with the rest of his gang, came through the air-lock in "*less* than four minutes." He was taken sick in the air-lock, and was unable to climb the stairs. He became unconscious while being brought up, and died two hours afterwards. The *post-mortem* examination showed that he had had no dinner, and only a light breakfast.

It appears that the temperature in the air-chamber was unusually high. The external air was 66°, and as no adequate cooling-apparatus was in use, the air from the pumps must have entered the caisson very much heated. On the following day, by noon, the air-supply came through a coil of 150 feet of copper pipe immersed in the river. The temperature in the air-chamber fell to between 60° and 70°.

The doctor at once transferred the ice-box to the air-lock, and enforced his rules strictly. Fourteen cases occurred between the 11th and 27th, when the filling was completed. Only one was serious. This patient had not only paralysis of the legs, but fever and hemorrhage of the lungs. He had evidently been unfit for the work. He recovered in two weeks.

During the last few days there was room for only three or four men to work at once, and they changed gangs every half hour. Moreover, the doctor was present and examined every man once in six hours.

In spite of the efforts to keep down the temperature, the men complained of the heat, and of being very tired on coming out, and not infrequently of having headache. As soon as a man complained of pain or numbness, he was required to rest over one watch.

To prevent the men reckless of danger from passing through the air-lock too rapidly, the size of the inlet and discharge-pipes was changed, so that though the valve was *wide open*, the stipulated time could not be curtailed. One can imagine the imprecations bestowed on the "slow coach" by men in haste to get out.

SUMMARY OF CASES REPORTED FROM THE EAST AND WEST PIERS.

	Cases.
At the City Hospital, reported by Dr. E. A. Clark	35
Reported by Dr. Paul F. Eve (other hospitals and elsewhere)	3
Reported by Dr. A. Jaminet	49
Not reported by physicians	4
Total	91
Number of serious cases	30
Number crippled for life (apparently)	2
Number of deaths*	13

The whole number of men who worked in the air-chamber of the East Pier was three hundred and fifty-two. This num-

* One of the men did not die till the following year, but as he remained all the while a helpless paralytic, his death is properly attributed to the air-chamber influence.

ber includes many of those who worked at the West Pier, but many, probably one hundred and fifty others, who worked only at the West Pier, are not included. The ninety-one cases given above include only the deaths of those requiring medical treatment. There were probably a full hundred others slightly attacked, eliciting a few groans, but more jokes.

In his report of October, 1870, Mr. Eads gives the names of forty-eight men "who were employed in the caisson of the East Pier from the time it entered the bed of the river until it was filled with concrete."

EXPERIENCE OF THE MEN AT THE EAST ABUTMENT.

Three important changes had been made in the East Abutment, intended to subserve the comfort and health of the men: First. The air-locks were 8 feet in diameter instead of 6. Second. The candles lighting the air-chamber burned in globes which discharged the products of combustion into the open air. Third. An elevator in the central shaft was used to bring up the men at the expiration of their watches.

The first change arose from a desire to give the men more air to breathe while waiting in the lock. The second contributed certainly to the comfort and cleanliness of the men, and hence to their health. The elevator seemed indispensable, and justified itself a thousand-fold. The winding stairs numbered one hundred and ninety steps. What a torture to weary "submarines!" The eminent French engineer, Malezieux, after visiting St. Louis to see the work in progress, spoke enthusiastically of this improvement.*

The success of the regulations finally adopted at the channel piers on the suggestion of Dr. Jaminet led the chief engineer to place him in charge of all sanitary measures at the East Abutment. He entered on his duties when the caisson was 56 feet below the surface of the river; pressure, 27 pounds (above the normal). He found seventy-six men at work in the air-chamber. They were in four gangs: two by day and two by night, working six hours each: two hours on and two off. *All of them had worked in the air-chambers of the East or West Piers.*

During the month the number of men was increased to one hundred and forty. Of one hundred and thirty-three applicants examined, sixty-seven were rejected as unfit for the work. The most common cause was "general debility, caused by intemperance." No men were received older than forty-five years.

A building with berths, mattresses and blankets, and an hospital, were provided. The men were required to lunch at the abutment. Beef-tea was furnished to every man at his meal. No one was allowed to leave the works till one hour after his work for the day (or night) was over. The men were examined daily, and no one was permitted to enter the air-chamber unless in good working condition.

When the pressure reached 32 pounds, a day's work was reduced to two watches of two hours each, with rests of four hours between them, and perfect rest lying down for one hour after the second watch. The doctor had two slight cases of paralysis, but in each case the patient recovered in twelve hours so as to go home alone.

When the pressure reached 34½ pounds, the work was reduced to three watches of one hour each, with intervals of rest three hours long. Two men were taken sick, who recovered in twelve hours.

When the pressure was 40 pounds, the elevator was stopped for about twenty-four hours (in consequence of a leak in the wall of the main shaft), and the men had to climb one hundred and seventy steps after each watch. Four men were taken sick with pains and paralysis about twenty-five minutes after coming up the stairs. They all recovered in about twelve hours. After the elevator came in use again, no case occurred for four days, when, the pressure being 42½ pounds, six men were taken, though within twelve hours all were discharged from the hospital. The doctor asserts that the men fell sick partly through their not resting as ordered. On reaching a depth of 100 feet, by order of Mr. Eads, a day's labor of the air-chamber

* "What an advantage not to have to waste the time needed for descending and climbing a height equivalent to ten stories of a Parisian house! What relief to the men, generally exhausted at the end of their task! What convenience for the transmission of orders, for the introduction of tools, for communications of all sorts."—[*Annales des Ponts et Chaussees*, 1874, p. 349.]

men was reduced to two watches of forty-five minutes each. No more cases of sickness for ten days.

During the next ten days the air-chamber was full of water, in consequence of the tornado of March 8, 1871.

Two cases happened on the 18th, while the elevator was still out of repair. Both cases were light. Pressure, 46 pounds.

The comparative immunity enjoyed thus far at the abutment seems to have made the men reckless, and the doctor complains that they would not obey orders as to lying down after coming from the air-chamber, and as to not drinking water for thirty minutes after coming up. (No reason is given for the rule last referred to.)

One man worked two hours instead of forty-five minutes, and then did not lie down on coming out. He was taken in the usual way. Some half-dozen light cases, easily disposed of, occurred previously to April 14, when the pressure was 49 pounds. On that day a man was taken, who died two weeks later. This was the *only death* by compressed air at the East Abutment; and it would appear from the report of the doctor and of Superintendent McComas that the man brought his fate upon himself. He had failed to bring his dinner, so went home to eat it, contrary to orders. Then, on his way back, he "filled himself" with beer. Moreover, on coming up from his second watch, he left the works before his hour of rest was up. These facts were duly recorded by the superintendent on the day of their occurrence. On reaching home in the afternoon, the man was taken sick with vomiting. His dinner had evidently been eaten with great haste, and was still undigested. In a few minutes general paralysis supervened. The history of his case up to his death shows that the man's blood was in a bad state. He had worked in the air chamber over three months.

Two slight cases close the list; one was that of a man who walked up the stairs instead of taking the elevator, and was taken sick on reaching the top.

SUMMARY OF CASES AT THE EAST ABUTMENT.

Number of cases	28
Died	1
Completely recovered	27

Of all those that died from the effect of compressed air, eight were examined *post mortem*. In all cases the brain and spinal cord were congested. As a rule, the interior organs of the body were excessively congested. There was no doubt that the immediate cause of death lay in the influence to which the men had been exposed in connection with their work in compressed air, though in nearly every instance the *post mortem* revealed weaknesses and susceptibilities, which, could they have been known earlier, would have caused the rejection of the men by the medical examiner. When death did not intervene for some weeks, the developments were much confused. Four of the reports are given below, in the belief that the importance of giving full information justifies their insertion.

Theodore Louis Baum was a German, twenty-one years old. He was admitted to the hospital March 22d, 1870; he died the next day. The coroner reported:

"On examining the contents of the cranium, the substance of the brain was found overcharged with blood, oozing freely from minute points on section. The meninges were also highly congested, and considerable serous effusion between them, most marked under the arachnoid. The spinal canal was also opened and examined, and about the some condition existed here as in the brain. The effusion under the dura mater was well marked. There was also found in the inside of the dura mater, at several points, small clots of extravasated blood. In examining the thorax, the small capillaries of the pleura and pericardium were found highly injected. The lungs were highly congested, but much less than the other organs. All the abdominal viscera were entirely congested; clots of extravasated blood were found in the kidneys, and small dark patches on the mucus membrane of the bladder, resembling ecchymosis."

John Sayers, twenty-two years old, was admitted to the hospital after his first watch of two hours. He died in twelve days. The coroner reported as follows:

"The brain and spinal cord were found highly conjested, the latter being softened in many places to pulpy consistency. There was evident subarachnoid effusion, and probably more than a normal quantity of fluid in the dura mater of the cord. Small clots of extravasated blood were found at different points on the external surface of the latter membrane. All the abdominal viscera were surcharged with blood, the lungs suffering less in this respect than any of the other organs. There were clots of blood found in both kidneys; one of the ureters was very much enlarged."

Henry Krausman, age twenty-seven years, a German, was taken sick March 21. He died in the hospital two days afterward. The *post mortem* was recorded as follows:

"The whole contents of the cranium were found highly congested, with effusion beneath the arachnoid, the vessels of the latter membrane being highly injected. Blood oozed freely from the substance of the brain on section. The spinal cord presented pathological conditions precisely like those of the brain, with the addition of the existence of clots of extravasated blood at different points inside the dura mater; there was also a congested condition of the thoracic content, less marked probably in the lungs than in the other organs. The abdominal viscera were very highly congested, with extravasation of blood in the kidneys. The mucous membrane of the bladder was healthy, and a small quantity of bloody urine was in the bladder."

William Sayler was a German, thirty years old, of medium stature, and well built. He worked three months at the West Pier, where the pressure was for two weeks 40 pounds to the square inch, from which he suffered no inconvenience.

On May 11 he began work at the East Pier, where the pressure was 49 lbs. above the atmosphere. He worked from 8 to 9 o'clock A. M., and felt well after coming up. He went ashore at 11:30. At 1 P. M. he resumed work, and finished his watch without complaint. While in the air lock, at 2 o'clock, he felt sick, and was unable to ascend the stairs. He became insensible while being carried to the hospital, where he remained insensible till 4:20 P. M., when he died.

A *post mortem* examination was held, sixteen hours after death, by Dr. Jaminet, which elicited the following facts:

"*Cranium.*—All the blood-vessels of the scalp, as also all the membranes covering the brain, were highly congested, and about two ounces of serum escaped from the vertebral canal when the brain was removed. The brain was congested and two ounces of serum found in the ventricles.

The heart was of normal size; the right ventricle, as also the left, were normal. The lungs were inflated and of normal appearance, but there were large *adherences* around the base of the right, which seemed to be of long standing. The liver was normal as well as the spleen. The kidneys were normal, as was also the bladder, but empty. The stomach normal *and entirely empty; no traces of food were found*, which confirmed my opinion that this man had not taken any dinner, and probably a very light breakfast, but had been drinking beer and whiskey quite freely, as it was afterwards ascertained."

GRAND SUMMARY.

Total number of men engaged in the air chambers of the East and West Piers and East Abutment, about	600
Cases reported by Dr. Clark	85
Cases reported by Dr. Eve	8
Cases reported by Dr. Jaminet	77
Cases not reported	4
Total	119
Number of deaths	14
Number of *post mortem* examinations	8
Number known to be crippled	2

A majority of all cases, including at least three-fourths of those that died, worked in the air chamber only *one day*, and generally but *a single watch of two hours.*

Two-thirds of those taken sick at the East Pier were attacked immediately on coming out, either on the stairs or as soon as the top was reached. In other cases the men were generally attacked within half an hour.

At the East Abutment, with the exception of the man who died, as already detailed, there were no serious cases. Of these twenty-eight cases were—

Attacked immediately after leaving the air lock	4
Attacked 15 minutes after leaving the air lock	4
Attacked 20 minutes after leaving the air lock	12
Attacked 25 minutes after leaving the air lock	2
Attacked 30 minutes after leaving the air lock	6
Attacked later than 30 minutes after leaving air lock	0
Total	28

I have now given a statement of facts and personal observations sufficiently full for an intelligent discussion of the whole matter. I frequently visited the air chamber of the East Pier, but my visits were short, and I felt no special inconvenience. Neither Mr. Eads nor his assistants, nor even the superintendent, though almost daily in the air chamber, can add much to our stock of information. None of them suffered beyond an occasional numbness, or a slight pain in the joints. As a rule, chance visitors had no personal sufferings to report beyond a "frightful pain" in their ears while making the first passage of the air lock. I have no record that any of the ladies who visited the air chambers ever suffered at all. Sometimes they bravely made the passage of the air lock while the gentlemen attending them were forced to withdraw.

I now propose to discuss at some length these very important facts, giving first the views of others expressed at the time, and finally, the conclusions to which I have been led by a very careful examination of all points.

The "Bridge cases" excited great interest and discussion in medical and scientific circles, but the physicians were not at all agreed as to the manner in which the compressed air acted so as to produce the symptoms exhibited.

Dr. E. A. Clark, physician at the City Hospital, believed that the increased atmospheric pressure upon the surface of the body compressed the superficial vessels and forced the blood in upon the interior organs of the body, causing the congestion observed. The lungs, having an internal equalizing pressure, were consequently least affected.

Another eminent physician thought that the men were poisoned by carbonic acid, which had been abnormally retained within the system while in the air chamber, but which was set free as soon as the pressure was removed.

Dr. Jaminet, the physician in the employ of the Bridge Company, thought that the men were sick from physical exhaustion, caused mainly by the rapid waste of the system, which, in his opinion, went on four times as fast under a pressure of four atmospheres as when under the normal pressure. Exhaustion was hastened also by labor in the air chamber, and the effort of climbing a long flight of stairs on coming out. He refers, in support of his theory, to the following well established facts: That in the air chamber, under four atmospheres, four times the usual amount of oxygen was inhaled at each inspiration; that the breathing was more rapid; that the men sweat profusely all the time they were in the air chamber; that the amount of urine secreted was larger than usual, and of greater specific gravity; that men whose vital energies were at a low ebb, and men with empty stomachs, were struck down first; that the muscular effort of walking up stairs increased the chances of sickness; and that long watches were more dangerous than short ones.

Dr. Jaminet's argument is founded on strong premises. If he does not reach the whole truth, he does a part of it. Certainly he was led to the adoption of measures, some of which worked admirably and went far to confirm his conclusions.

It is not so much my purpose to show that the views of others are wrong or inadequate, as to present an explanation which, so far as I know, is entirely new. While I award to Dr. Jaminet great credit for his professional zeal and considerable success in his efforts to account for and guard against the evils noticed, I insist that the theory of ordinary physical exhaustion fails to account for the phenomena observed.

My opinion is that *the vital energies of the men taken sick were to a great extent paralyzed by loss of heat.* This loss was due—

1. To the expansion of the air in the lock, while coming out.

2. To the expansion of the free gases and vapors within the body, when relieved of the abnormal pressure.

3. To the liberation of the gases held in solution by the liquids of the body.

4. To the severe physical effort of climbing the stairs.

I think that the chief loss of heat was suffered in the air lock when coming out of the air chamber, but that the loss continued, though more slowly, during the succeeding few minutes, while the men were ascending the stairs and the liberation of gases was going on.

The great loss of heat which necessarily attended every exit from the chamber, though incidentally noticed, seems not to have received proper consideration. A few words are necessary to show the importance of considering this point carefully.

The central air lock of the East Pier contained about two hundred cubic feet. It would hold thus ten men and 175 cubic feet of air. One hundred and seventy-five cubic feet of air under a pressure of four atmospheres would occupy, under the normal pressure of one atmosphere, seven hundred cubic feet, the temperature remaining the same. Now the loss of heat resulting from the expansion of this air, as a part of it is allowed to escape, is easily found by the rules of thermodynamics. Air at 70° expanding against a pressure diminishing from four atmospheres to one, *without receiving heat from surrounding objects*, is reduced in *temperature to 106° below zero!*

It was noticed that the escape cock was often covered with frost, and that the temperature, as indicated by a thermometer in the air lock, sometimes fell to 32°.* It probably fell very much below that point, but the thermometer was hung against the iron wall of the lock, from which it was all the while receiving heat, both by conduction and radiation, and it did not represent the temperature of the air in the center of the lock. Air at this low temperature extracted heat from the bodies of the men at a very rapid rate. From this cause alone a man would come out of the lock exceedingly cold. *This* loss of heat could be somewhat guarded against by the use of flannels, overcoats, and blankets.

But the absorption of heat through expansion takes place *within* the human body as well as *without* it. All the liquids of the body are surrounded by a certain amount of their own vapor; and gases, such as air, carbonic acid, etc., exist in cavities and pores all through the body, notably in the abdomen. Just how much this gaseous volume is, it is impossible to tell; but there can be no doubt that it exists in considerable quantities, and that gases pass by insensible degrees through all animal tissues. Now, in coming from a pressure of four atmospheres, there would be four times the normal amount of such gases in one's body. In passing through the air lock, three-fourths of this must imperceptibly escape by expansion, and during the expansion they must absorb and carry off heat from the interior of every organ of the body. Where the gases were most abundant, the loss of heat would be the greatest, viz., in the abdomen.

Very closely connected with this was the loss of internal heat through evaporation and the liberation of gases. *The amount of gas which a liquid can hold in solution is proportional to the pressure.* All the liquids of the body probably contain air and various gases in solution. After an hour's stay in an air chamber under a pressure of four atmospheres, the amount of gases held in solution in the liquids of the body was probably very nearly four times the normal amount. The absorption of the gases was attended by the evolution of heat and a feeling of exhilaration This feeling every visitor noticed on entering the air chamber. Now, on return to the air lock, and to a reduced pressure, this extra amount of gas began to escape, and one felt the effect of processes just the reverse of those previously experienced. The evaporation was attended by a loss of heat and a depression of the spirits. The increased vital energy gave place to a very low ebb of vitality and an all-pervading sense of frigid helplessness. It will be remembered that Faraday produced the most intense cold—*166° below zero*—by allowing very volatile substances to *evaporate* under a greatly diminished pressure.

These losses of heat can be considered only qualitatively; quantitative results are hard to reach, but an admirable and perfectly analogous experiment could easily have been tried, illustrating the heat absorbed by evaporation. Had Dr. Jaminet, after boiling water in the air chamber, taken a gallon of the water, every atom of which had a temperature of 297°, into the air lock with him, on his return to the upper air he would have found, when he came out of the lock, no matter how quick his passage, that the water remaining in his pail had a temperature of exactly 212°, and that considerable of the water had evidently *boiled away* in the lock. This experi-

* It should be remarked that the condensation of watery vapor into dew and frost around the escape-pipe slightly mollified the extreme cold by giving up its latent heat of evaporation.

ment was not tried, but every physicist knows that I am right in my statement of the result.

Now, how can we account for the loss of 85° of heat in the water? The answer is easy: A part of the water formerly confined by the pressure of four atmospheres has escaped from under a less restraint, and, while transforming itself into a gas, has robbed the water remaining of a portion of its heat. Any liquid saturated with any gas would, under a diminished pressure, part with its heat in precisely the same manner.

It is obvious that the liberation of gases held in solution by the fluids of the human body is a dangerous process. In escaping from the corpuscles of every liquid, and from within every tube and duct, there are two possibilities: First, the escape may be so rapid and violent as to rupture the minute tissues; and, secondly, the absorption of heat may be so great that the vital fluids may lose their vitality.

There is another point: The escape of gases held in solution by increased pressure is not instantaneous when the pressure is reduced; it requires time, even if the pressure is suddenly removed. Hence the internal loss of heat did not end with the exit from the air lock; it went on for some minutes, during which the vitality of the system was being reduced to a minimum.

There was yet one more demand made upon the vital heat and energy of the air-chamber men when they emerged, half frozen, from the air lock of the East Pier, namely: the mechanical effort of climbing 110 feet vertically before physical reaction had had time to set in, and while the loss of heat from evaporation and the liberation of gas was still going on. This effort alone, as has been found by experiments, reduces the temperature of the body. To raise 150 pounds 110 feet is equivalent to raising the temperature of one pound of water 22°. Hence twenty-two thermal units would be lost in the ascent by every man.

When we consider the combined effect of the four causes of loss of internal heat and vitality, taken in connection with the necessarily exhausted condition of men who had been laboring hard, secreting excessively, and sweating profusely, we cannot be surprised that they were chilled to their vitals, and that many of them failed to pass the minimum point without cramps and paralysis; we are rather surprised that so many escaped. We know that the temperature of the vital organs varies between very narrow limits. We know that sudden cold (as in the case of a man swimming in cold water) produces cramps in the legs, and sometimes intense headache. The almost invariable symptom in the Bridge cases was the paralysis of the bladder and the sphincter ani., both caused doubtless by loss of internal heat.

This brings me to the consideration of a very suggestive remark of Dr. Jaminet. Feeling, most certainly, that his theory of exhaustion did not fully account for the symptoms, he adds, with less regard for his theory than for a truthful statement of facts as he observed them: "The paresis [weakness] or paralysis is but the result of reflex action caused by *the spontaneous refrigeration of the whole system, but principally of all the abdominal organs.*" No more satisfactory confirmation of the truth of the explanation I have given could be asked than this observation of Dr. Jaminet.

One remark in reference to the time when the men were attacked. None were ever attacked on entering the caisson; none were ever sick when in the air-chamber, no matter how long the watch. In one or two cases the men felt sick just before leaving the air-lock. At the East Pier, two-thirds of the men were sick by the time they reached the top of the pier: the other third was attacked a few minutes later. At the East Abutment, twenty-four out of the twenty-eight taken sick were not attacked till from fifteen to thirty minutes after leaving the lock, and *none after the lapse of half an hour.* It is evident that about half an hour was necessary to reach the minimum point of vital heat; at that point the system began to recover. It is quite obvious that men exhausted by hard work, by insufficient food, or by dissipation, would be struck down early in the contest between vital strength and the inflexible laws of thermodynamics.

One word as to the pressure upon nerves, blood-vessels, and the brain. In nearly every *post mortem* examination, an increased amount of serum was found in the vertebral canal or within the cavity of the skull. I may not be physiologist enough to explain why this was the case, but I do not feel, as many do, that it furnishes a satisfactory explanation of the phenomena of sickness and death. It would appear that some yielded suddenly, and died in a few minutes; others were so prostrated, their energies were so far overcome and destroyed, that restoration was impossible, though sufficient vitality remained to prolong life for a few weeks; with others the struggle was long and severe, and the battle finally drawn, leaving the unfortunate victims with certain organs permanently impaired.

It must not be forgotten that *no one was attacked while under pressure*, nor while pressure was being applied; the fatal moment was when the pressure was removed, or within half an hour from leaving the air-chamber. Now, there can be no doubt but that the aerostatic and hydrostatic pressure throughout every part of the human body corresponded closely to the external pressure. In so far as there were cavities in the skull and spine containing gas and air, compression took place and additional air or liquid was forced into them. The internal pressure was sensibly equal to the external; any momentary difference produced acute pain, and no tissue was strong enough to withstand any great inequality. The pressure upon the spinal cord, upon the blood-vessels and the brain, *applied alike to every man, whether he fell sick on coming out or not.* If serum, or blood, or air was forced into a cavity, it was generallv absorbed, or returned without injury. A too rapid change of pressure would, of course (neglecting any question of heat), tend to cause head-ache, and do harm in the sockets of the joints.

As to the waste of the system while in the air-chamber, I think that Dr. Jaminet has greatly overrated it. Unquestionably, the waste was abnormally rapid. Men took twenty-one full inspirations per minute, instead of eighteen. It is true, a man inhaled four times as much oxygen as usual at a breath; but so he did of nitrogen, and, as usual, the amount of oxygen consumed was largely regulated by the amount of nitrogen mixed with it. Candles burned about sixty-seven per cent. faster under four atmospheres than under one. It is possible that the vital processes in the human body were accelerated in about the same ratio. Exact information as to the rate of waste and the influences of long watches is wanting. It is to be regretted that some one did not think to try experiments upon animals. Dogs, well fed, would doubtless have lived some days in the air-chamber, and, if carefully brought out, might have survived unharmed.

In conclusion, I agree with Dr. Jaminet, that only sound men should be employed: that they should not be exhausted by long terms of labor; that they should be well fed; that they should not pass in or out too rapidly: that they should, on coming out, be spared immediate hard work. For some unaccountable reason, Dr. Jaminet allowed twice as much time for entering the air-chamber as for coming out, though he saw that the coming out was the critical thing. His rule should be reversed: say eight minutes for going in and twelve for coming out, the pressure being 48 pounds above the normal.

But I would add to the above requirements one other, and *the most important of all*, namely: that *such a supply of heat should be given every man that he could lose a large amount and still have plenty left.* This could readily be done in various ways.

My conclusions may be stated in the form of—

RULES FOR THE MANAGEMENT OF MEN AT WORK IN COMPRESSED AIR.

1. Men must be sound and well fed. They should eat a hearty meal about one hour before entering the air-chamber.

2. The periods of labor should be diminished as the pressure increases: say, to two watches of two hours each per day under a total pressure of four atmospheres.

3. Men should have perfect rest and warmth for half an hour after coming out. This includes the use of an elevator.

4. The pressure in the air-lock should not be increased more than six pounds per minute, nor diminished more than four pounds per minute. If, when the pressure is increasing, any one has pains in his ears which cannot be removed by blowing his nose, or by swallowing

water, the inlet of air should be stopped and the man sent out.

5. Every man, just *before leaving the air-chamber*, should be required to swallow about a pint of hot coffee, tea, or soup.

6. There should be separate air-locks for *entrance* and for *exit*. The *exit* air-lock should be provided with heating apparatus, which should maintain a proper temperature and furnish direct heat to the bodies of the men.

Carefully observing these rules, it is probable that men can safely work under a pressure of five atmospheres.

SANITATION IN ANCIENT ROME.

From "The Builder."

There is every probability of Italian art becoming a thing of the past, especially if, as seems to be the case, the deterioration so noticeable on the Tiber should extend itself from one end of the Italian Peninsula to the other. Modern Italian architects and artists appear to be far behind their glorious predecessors, who have made their works serve for imitation to many generations of artists. But modern Italians have also deteriorated, compared with their forefathers, in other domains of what constitutes civilized life. This remark applies especially to the question of sanitation. We know, at least travelers very often do to their cost in the loss of health, that in sanitary matters Italy does not occupy a very high place; and from a lecture recently delivered by Professor Uffelman, of Rostock, it appears that in this respect they are not nearly on the level occupied by the ancient Romans. To do them justice, however, it ought to be added that, for that matter, they are no worse than other nations, who very often are behind their ancestors in a good many things, and might well learn from them. At present however, we have only to deal with Rome; and from the lecture to which we have referred, and which throws much light on a subject hitherto very little known, it appears that in ancient Rome, the metropolis of former times, there existed important institutions for preserving health amongst its inhabitants.

Although there were then at Rome no sanitary inspectors, in our modern sense, the Ædiles and Censors were charged with sanitary functions. It was the Emperor Augustus who first appointed inspectors of water-supply and superintendents of sewers, who exercised a sort of police supervision also over the river of the city, the Tiber. The city of Rome was early provided with a system of sewers, which at first, at the time of King Tarquinius Priscus, only had the object of draining some parts (amongst them the Forum) of the city, but which later likewise served the purpose of modern sewers, that of receiving and carrying away all descriptions of refuse. Under Tarquinius Superbus this system of sewerage was completed by the construction of the Cloaca Maxima (the largest sewer), leading to the Tiber, which still exists; and, whatever be the difference of opinion as to the provision of large sewers, may well rank with the best sewers of our time, so far as regards excellence of construction. For five centuries this system of sewerage was carefully preserved, extended, repaired, and cleaned. But with the decline of the city this great work was permitted to fall in ruins, and only the principal sewer remained, which has been preserved down to our day, but choked up by mud, and at its end toward the Tiber filled up to two-thirds its height.

The second fundamental condition for the preservation of the public health, that of providing the city with an abundant supply of good water, was done full justice to in ancient Rome. When the water in the Tiber, in consequence of its contamination by the population inhabiting its banks, could no longer be used for drinking, the Censor Appius Claudius constructed an aqueduct, for the greater part underground, from Praeneste to Rome, which was called after him the Aqua Appia. Fifty years later this was supplemented by a second; and, after other seventy years (144 B.C), by a third aqueduct, the Aqua Marcia. The latter brought the water from the Sabine Mountains, was thirty-two miles long, and supplied excellent water, which for centuries refreshed thirsty Romans, and which was originally constructed at a cost of £2,000,000, an enormous sum at that time. It was in ruins for many years, but was restored ten years ago, and has since then furnished Rome with its water supply. Numerous other aqueducts, some of them very magnificent and gigantic, were built. Toward the close of the Empire, nineteen aqueducts, fourteen larger and five smaller ones, conducted the water to the metropolis. At the end of the first century after Christ, ten aqueducts supplied a daily quantity of 33,000,000 imperial gallons of water to Rome. As four-eighths of this volume were used by the Thermæ, or public baths, and one-eighth by the imperial palaces, there remained yet three-eighths for the use of private consumers, the quantity supplied to the two million inhabitants of the metropolis being sixty-two imperial gallons of water per head per day for domestic use. The water was conducted through the city in leaden or earthenware pipes. The aqueducts were fully protected by law. No buildings could be erected over them, no trees planted near them. Heavy punishment was inflicted on persons polluting the water or damaging the aqueducts or conduits. With the decline of Rome, those splendid institutions also fell into ruins; but they were partly destroyed by hostile armies or besieging forces, in order to compel the Romans to surrender their city.

Public baths reached a state of perfection in Rome such as has not been attained by any other nation. At first, of course, only the Tiber formed a natural basin for ablutions; later artificial public baths were constructed, and under the emperors the Thermæ were introduced. Those magnificent bathing establishments not only furnished cold, warm, and hot baths, but they supplied also shampooing baths and cold ablutions; anointment of the body was likewise practiced there. Those institutions still serve in many cases as patterns for baths erected now for our well-to-do classes, but which at that time existed in incredibly large numbers, the use of them being, besides, free to all comers. But those establishments did not bring with them the unmitigated advantages it was probably at first thought they would furnish; they degenerated, and became the abodes of idleness and hotbeds of vice.

There was no want of regulations in ancient Rome as to height of houses and width of streets. When, after the great fire, under Nero, the city had to be rebuilt, regulations of this description had to be strictly followed. There was likewise an abundance of public places of amusement, walks, and public gardens. The Government also looked to the supply of provisions, its solicitude at first being merely confined to taking care that a sufficient quantity of corn was continually stored in Rome. Many descriptions of food—for instance, meat—were also inspected. Of the stored grain, large quantities were given away to the poor since the time of Cæsar; during the reign of Pompey very nearly £1,000,000 was spent for this purpose annually.

There existed many charitable institutions, although there were few of them according to our notions. The Emperor Nerva sank large funds, the interest of which was appplied in supporting the children of poor parents and orphans. Trajan placed nearly 5,000 children on the list of recipients of corn. Antonius Pius founded an institution for poor girls. Hospitals did not exist very early; they sprang up under the influence of Christianity, their number amounting in the ninth century to over twenty. Nothing was done in the direction of public care for the poor until the middle of the second century after Christ. Antonius Pius appointed communal physicians, who were free from taxes, but who were under the obligation of rendering certain services to the State and the commune, and who had, among other things, to treat gratuitously all the poor of their respective districts. Alexandrus Severus was the first to pay them a salary, and gave them the name of *Archiatri populares.*

The ancient Romans did not permit the industrial classes to poison the air for them. Fullers, who used urine in a state of putrefaction in the manufacture of cloth, had to carry on their calling outside the city gates or in its remote quarters. Roman law-makers had a watchful eye on the disposal of the dead. At first, deceased persons were interred inside the city; later those interments were prohibited, and a public cemetery was laid out outside its walls. Funeral funds existed very early in Rome, which paid, as in our time, a fixed sum at the death of a member, if the latter had subscribed regularly. Cremation was introduced at the time of the Decemvirs, at first only in the case of individuals, but later, after Sulla, cremation became more common. At one time this was the general mode of disposing of the dead, but committal to the soil was never entirely abandoned, and with the spread of Christianity became again more general. But in the beginning of the second, during the third and fourth, and the beginning of the fifth centuries, the Christians used the subterranean cemeteries, the so-called Catacombs, in which the bodies were placed in hollows cut in the walls of the passages driven through the tufaceous limestone underlying Rome, the cavities being afterwards closed by marble slabs, on which the names of the deceased were engraved. In time these catacombs became more and more complicated.

From the above it will be seen that the institutions and hygienic regulations of the ancient metropolis were very remarkable, and in some respects at least much more perfect than at the present day in many cities and towns, the inhabitants of which think a great deal of their sanitary arrangements.

COMPRESSED AIR, STEAM, OR ELECTRICITY FOR TRAMWAYS.

From "English Mechanic and World of Science."

The success of the electric tramway in Berlin and Paris, and the proposal that has been recently made to construct an elevated circular railway in the latter city to be worked by electricity, have served to attract renewed attention to the debated question of the best motor for street tramways. It is conceded that for suburban districts steam may be used with impunity, but many objections and much opposition is offered to its introduction into the streets of towns; hence the persistence of the advocates of compressed air motors. At the recent meeting of the Institution of Mechanical Engineers, Mr. Scott-Moncrieff read a paper on compressed air motors, in which, while admitting that the steam engine was the cheapest and most efficient motor, he contended that in many cases compressed air engines could be used with advantage and even with economy. The success of the electric motor of Messrs. Siemens, and the fact that the municipal commission of Paris have advised the experiment of an elevated electric railway in that city, introduces another rival, and tramway companies will now find it still more difficult to determine on the motor they will employ instead of horses. Recently on the Walton tramways, near Liverpool, a series of trials with steam engines of different designs has been made in the presence of Major General Hutchinson, of the Board of Trade, so that if it is possible to ascertain the actual expenses on an electric tramway, there ought to be no difficulty in determining which motor, all things considered, is most desirable. It is obvious that, so far as dead weight is concerned, there is little to choose between steam and air motors, for if the former need generators and engines, the latter require reservoirs, which being strong enough to resist high pressures are necessarily heavy. With the electric tramway, on the contrary, the dead weight of the motor is very small comparatively, but it is expensive in first cost, and may be found "heavy on repairs," an item which has yet to be calculated with approximate accuracy. The electric motor compares with the air motor in the fact that both take their power from a fixed steam engine, and it is clear that the first question asked by an engineer will be, what percentage of the power developed by the steam engine is transmitted respectively by the two kinds of motor, for, other things being equal, if the electric motor is capable of transmitting a greater percentage of useful effect, the air motor is out of court. In the case of the steam motor we may assume that a locomotive is as economical as the fixed generator and engine, and as its power is applied direct, it is obvious that it is more economical than either air or electricity; but it possesses disadvantages which do not pertain to its rivals, in the shape of smoke, dust, exhaust steam, heat, and liability to explosion—though as far as the last is concerned, it is impossible to conceive that there is not some risk of rupture in the case of reservoirs containing air at pressures of 1000 lbs. and upwards. In the paper above mentioned Mr. Scott-Moncrieff gave a number of technical details of the construction of his motor, and of the arrangement of the valves, etc., by means of which the highest possible duty was obtained from the compressed air. The car to which it is attached travels seven miles with one charge of air, the maximum pressure of which is twenty-six atmospheres—say, 400 lbs. The car carries forty passengers, and makes about twenty-five stoppages, and the cost of fuel, on the "large scale," is one halfpenny per mile, coal costing 10s. per ton. Mr. Scott-Moncrieff contends that the insignificant saving effected by heating the air before passing it into the cylinders is not worth having on such a route, and relies for the efficiency of his motor, which is perhaps the best of its kind, on careful regulation of the rate of expansion, which is effected automatically, but requires alteration when the pressure falls or rises beyond certain limits. On p. 2, last volume, we gave a short account of the Mekarski air locomotive, which had been used for some time on the tramways in Nantes; but little or nothing has been done with it in London, where, however, Col. Beaumont's motor is now at work between Stratford and Leytonstone. This latter motor, which we described some time ago, has an initial pressure of 1000 lbs. in the reservoir, and, at one time, was thought so highly of that it was subjected to a series of trials on the Metropolitan Railway. In the course of the discussion on Mr. Scott-Moncrieff's paper, however, Mr. Tomlinson, jun., engineer to the railway, said he had made an estimate as to the cost of supplying compressed air for the engines that ran out of Aldgate alone, and he found that twenty-six large Cornish boilers would be required to work night and day, and these, with the engines, machinery, and other plant, would occupy about five acres of land, and would cost more than the whole of the locomotives at present on the line and their working expenses for a long time. The fuel cost of train haulage on the Metropolitan is, according to Mr. Tomlinson, 1½d. per mile for a train of 150 tons weight, with coals at London prices, whereas Mr. Scott-Moncrieff's car, weighing about 7½ tons, and carrying only forty passengers, costs, for coal at Glasgow prices, ½d. per mile. The weak point of the air-propelled engine is, apart from financial considerations, its want of range of power, for if from any circumstance it is brought to a standstill for lack of power, there it must stick, whereas a steam motor, by getting up pressure, could overcome the difficulty and proceed on its journey. The dead weight of steam and air motors is not altogether a disadvantage, for it gives adhesion; but the chief difficulty in introducing steam engines is the state of the tramways, which, as a rule, are not capable of withstanding the wear and tear of such loads. In the experiments above referred to, made recently on the Walton tramways, three detached steam motors and one combined engine and car were tried. The first was a detached motor, made by Messrs. Hawthorne, of Newcastle, and completely enclosed in a light ornamental case about the height of an ordinary tramcar. This machine worked easily, without noise, emitted steam only now and then, and quite suppressed smoke, while the brakes acted quickly and effectively. Similar results were obtained with a detached motor made by Duncan and Wilson, of Liverpool, except that there was a little noise. Of the detached engines, that which attracted most notice was Mathew's patent, which has a patent locomotive boiler, and the motion work of which is of steel, including the wheels and axles. This engine drives from either end, and is worked by one man, the whole of the driving parts being placed outside the frames and carefully shut in with casing to exclude dust. The combined engine and car tried was Apsey's patent, made by

Ormerod, Grierson and Co., of Manchester. In this device the boiler is carried at one end, the engines being in the center and beneath the floor of the car; but the arrangements are such that the driver can stand at either end. A light awning protects the outside passengers from any vapors or dust that may escape from the chimney. The weight is in this case all used for adhesion, and the car is stated to have run with greater smoothness and less noise than an ordinary horse car. All these steam motors are well within control, possessing sufficient brake-power to stop them within their own lengths from the maximum speed allowed on tramways; they are practically free from escapes of steam and smoke, and, in short, are well adapted for the work for which they were designed. Steam motors have been in use on some of the tramways of Paris with success; but a variety of considerations have just now attracted the attention of the Parisians to electricity as a means of working their "metropolitan railway." The Parisians, it seems, do not favor the idea of an underground line, which, moreover, could be made only at great expense and at considerable risk to property immediately in the neighborhood of the tunnel; but the streets are now so crowded that some inexpensive method of getting from one part of the city to another is becoming more and more necessary. Tramways have been laid along nearly every possible route, but on some of the principal main lines of traffic they cannot be laid for want of space. The Siemens electric tramway has, however, been favorably reported on by a Committee of the Municipal Council, and is approved by the Parisians; while a French engineer has exhibited a complete scheme for an elevated railway to be worked by electricity, so that M. Chretien's idea is not unlikely to be carried out. The great objection to an elevated railway is its appearance, which will necessarily tend to the disfigurement of the streets and roads through which it passes. On this point it is suggested that the viaduct need not be an ugly mixture of pillars and girders, but may be made ornamental in finish, while it would occupy only a small portion of the wide boulevards through which it would run. M. Chretien's plan is so far complete that it consists of a network of lines with stations at intervals of about 400 meters, so arranged that would-be travelers standing in the heart of Paris would not be more than about 200 meters from a station. The proposed width of guage is about 1¼ meter, which would involve a total width of 4½ meters—say 15 ft. The two lines would be carried on girders and pillars, and would be separated by a deep lattice girder in the center. The columns would be 130 ft. to 160 ft. apart, and, the line being floored throughout, would form a shelter from the rain to foot passengers. The vehicles suggested by M. Chretien are 26 ft. long by 5 ft. wide, with doors to open and close automatically at each station. Four places are suggested as suitable sites for locating the engines and dynamo machines, the estimated power of which, for working the line, is set out in detail; but it is obvious that, if electricity is to be installed on such a scale as is implied by a railway, it would be advisable to put down engines and machines capable of also supplying current for lighting purposes in the neighborhood. Estimates of cost and working expenses are of little value at the present stage of the railway; but it may be mentioned that M. Chretien enters at considerable length into the question. For instance, he calculates that the working cost of a line running from the Madeleine to the Bastille would be 40 centimes for each "train," or vehicle, so that four passengers at 10 centimes would pay expenses, and as the car would hold 50, there would be ample room for earning a good profit. The line would be worked on the rapid system; that is, instead of long trains at intervals, single vehicles would call at the stations nearly every two minutes; the fare would be uniform for all distances throughout Paris, and there would be no distinction of classes. Between the two stations above mentioned, is a distance of two and a half miles, and if an electric car can be worked over that length of line for four pence, which is a small fraction more than 40 centimes, there is an important future in store for electric railways. As mentioned above it is probable that an experiment at least will be made, most likely in the Boulevard Voltaire, which is now nearly completed, and if the Parisians are satisfied with that, they will no doubt put up with the disfigurement of their beautiful boulevards for the sake of the convenience of the railway. In this country it will be simply a question of cost, and if electric railways can be worked economically, they will settle the vexed question of motors for tram lines.

A PROPOSED ASSOCIATION OF WESTERN HIGHWAY BRIDGE BUILDERS.

By J. A. L. WADDELL, C.E.

Written for Van Nostrand's Engineering Magazine.

That such an organization as the one above mentioned is really needed is apparent to every reasonable man who travels to any extent in the Western country.

Not more than ten or fifteen per cent. of the highway bridges in the West are built upon sound specifications, and of these many are not as strong as they are claimed to be. This is proved by the number of bridge failures of which one reads from time to time in the newspapers, though, if the truth were told, such matters are very often hushed up or the failure is attributed to a washout, a tornado or some other cause which man is supposed to be powerless to resist. It is true that once in a while there does come a hurricane powerful enough to overturn the best of bridges, but such storms are few and far between.

Every bridge should be built so as to resist, without injury to any of its parts, the highest wind pressure observed in heavy gales. As for washouts, they are usually due to the short-sighted policy of the supervisors, to whom is entrusted the responsibility of directing how the bridges are to be built. Rather than make the spans a little longer and raise them a little higher, thus increasing their cost and that of the approaches, they prefer to block up the stream with the foundations and to run the risk of high water reaching the bridge. There is really no excuse for a washout except a gorge of ice or timber, and even this can, in most cases, be avoided. But washouts and tornadoes are not the true causes of most of the bridge failures, for many structures succumb without the assistance of either high wind or high water; they fail simply by reason of faulty design, which makes them unable to withstand the stresses developed in them by passing loads. Worse than this—many of them are scarcely fit to sustain their own weight!

This is a pretty bad state of affairs, and what has been done to ameliorate it? Very little.

About a year ago Professor Vose issued a pamphlet entitled "Bridge Disasters in America; the Cause and the Remedy," which should have done considerable towards raising the standard of American bridges. Unfortunately the work has not met with the reception it deserves, and bridges are built in about the same style as they were before its appearance.

The "remedy" suggested by Prof. Vose is the appointment of State engineers, whose duty it would be to examine before erection the diagrams of stresses and sections of all bridges to be built in their States, and to inspect at least twice a year all the existing bridges.

The pamphlet concludes as follows: "Thirty bridges on an average break down in the United States every year. No system of inspection or control at present existing has been able to detect in advance the defects in these structures, or to prevent the disasters. A system, practical, simple and inexpensive, can be had, which, if properly carried out, will insure in nearly all cases, if not all, the public safety. It lies with the public to say whether or not it will have such a system."

Well, the public, by the indifference it has shown, has clearly indicated that it does not deem such a system necessary; and nothing but a long series of bridge disasters involving great loss of human life will ever awaken it to the fact that something must be done to prevent such accidents.

Now, why cannot the bridge companies themselves undertake the duty that the public refuses to assume?

Every first-class bridge company recognizes the fact that it is to its interest to build good substantial structures, but many of them are forced by the closeness of competition with inferior companies and local bidders to erect bridges that are not approved of by their engineers. They would, probably, very gladly do what they could to improve the bridge business, but are restrained by force of circumstances.

To show how the difficulty may be overcome is the object of this paper.

Let there be formed during the coming winter, when bridge builders and engineers will be comparatively at leisure, an association of all the principal bridge companies of the West, the object of which shall be to *enforce* the building of firm substantial structures.

The word "enforce" is used advisedly, for such an organization would, on account of the standing of its members and the praiseworthy object of its existence, wield great power. It could dictate to county commissioners what quality of bridges they should build, and could prevent the erection of all bridges not up to a certain standard. By taking into the association the manufacturers of bridge material, an arrangement could be made by which local bidders would be unable to obtain iron for doing inferior work. This would soon render the existence of that genus a thing of the past.

By the term local bidder is meant an individual residing in the county where the bridge under consideration is to be built, who has assisted in some capacity or other at the raising of two or three structures, or has been practicing the trade of carpenter or blacksmith, and who, with no knowledge whatsoever of mathematics or the laws of mechanics, gets into his head the insane idea that he can design and build bridges, and proceeds to put that idea into practice. Nearly every county contains at least one specimen of this kind. It is to these men as well as to inferior companies that are due the low standard of American highway bridges, and the numerous disasters which occur every year.

The organization of the association proposed would be a simple matter; the first step to be taken at the meeting of the representatives after choosing a chairman would be the appointing of a committee to draw up a constitution and by-laws, and another, composed of the best engineers, to make out specifications, tables, &c., regulating the style and strength of bridges to be built in future. Sufficient time should be allowed these committees in which to report, as there would undoubtedly be a good deal of discussion before all the various theoretical and technical points could be satisfactorily settled.

The general scheme of the association should be that each company deposit with the treasurer a certain sum of money in cash, say one thosuand dollars, to be held by him as long as the company be represented in the association, as a guarantee that said company will comply with all the rules and regulations of the association. Should at any time the company or any of its authorized agents fail to do so, a standing committee of three to act as judges should decide as to how much of the deposit be forfeited for the offence, and the company should be deprived of all the rights and privileges of membership until such time as the amount forfeited be replaced. In order to insure its speedy replacement, a further fine of so much per month, after the first month, should be added until the deposit be brought up to its original amount.

With the money accumulated from fines, interest on guarantee deposits and, if necessary, annual dues, the association could make many needed experiments upon resistance of bridge materials, and could have the results printed in a publication of its own. Discussions in the papers of the association from time to time would originate new rules, and thus elevate the standard for bridges. But—some one may say—suppose two or three companies refuse to enter the association, will not this be sufficient to prevent its organization? Not at all. Should any company refuse to join the association and continue to build inferior bridges, it would soon be forced either into the association or out of the business.

This statement may sound a little like an infringement of the privilege, that every American has, to do as he pleases, and may seem like coercion of the weak by the strong, of the few by the many; but such need not be the case. The privilege of membership should not be withheld from any one willing to deposit the guarantee and to comply with the regulations of the association.

Some one may suggest that, if all the bridges in the country be built upon one set of specifications, there would be no chance for improvement by variation in design. By no means; the specifications of the association would limit the *weakness* of bridges, not their *strength*, and any one would be at liberty to make all the improvements he might desire, and ought to be encouraged to do so by the association as a body.

Someone may observe that, if all bridges are to be built upon scientific principles, it will be a little hard upon those who have not received a scientific education. All very true, yet such persons have three courses to chose from: first, to post themselves; second, to employ skilled labor; third, to build after the model of some one who is better instructed. Besides, the tables, &c., of the association would be of great assistance to such persons, enabling them to make good designs with very little calculation.

But then—some one may object—this association would be a monopoly. In one sense perhaps it would, in that it would prevent ignorant men from doing work which ought to be left to those who have spent years in educating themselves for the purpose.

In short, there can be no reasonable objection to the proposed association, and not only would it be a benefit to the bridge companies, but would be also a great boon to the country at large.

THE PRESSURE OF WIND.

From "The Architect."

More than a century ago John Smeaton, the engineer, had a table prepared by his friend, Mr. Rouse, showing the force of wind in pounds to the square foot. It is still reprinted in engineers' pocket-books and other abstracts of science. At one mile per hour the force was said to be .005 lbs., and it ranged to 49.200 to the square foot, which was supposed to represent a hurricane having a velocity of 100 miles an hour. Smeaton said that the evidence for those numbers where the velocity exceeded fifty miles in an hour did not seem of equal authority with those of fifty miles and under. He also explained how the pressure was derived from the velocity, the equation being $P = 0.00492V^2$, where P = pressure in pounds avoirdupois, and V = velocity in miles per hour.

According to experiments by Hagen, the pressure of the wind against an inclined rectangular plate is nearly proportional to the square of the velocity, and the cosine of the angle of incidence of the wind. It was also found that the pressure depends to a great extent on the shape as well as the surface of the resisting body. The following table will show the differences between the results obtained by Smeaton and Rouse and those by Hagen:

Velocity of wind.		Pressure in pounds per square feet plane surface.			
			Hagen.		
Miles per hour.	Feet per second.	Smeaton and Rouse.	Circular surface.	Square surface.	Triangular surface.
0	0.	0.	....	....	....
1	1.47	0.005	0.003	0.003	0.004
2	2.93	0.02	0.014	0.014	0.014
3	4.4	0.044	0.03	0.031	0.032
4	5.87	0.079	0.054	0.055	0.057
5	7.33	0.123	0.085	0.086	0.088
10	14.67	0.492	0.339	0.345	0.353
12	17.6	0.711	....	....	....
15	22.	1.107	0.763	0.777	0.795
20	29.34	1.968	1.356	1.382	1.418
25	36.67	3.075	2.119	2.159	2.208
30	44.01	4.429	3.052	3.109	3.18
35	51.34	6.027	4.154	4.232	4.328
40	58.68	7.873	5.425	5.527	5.653
45	66.01	9.963	6.866	6.996	7.155
50	73 35	12.3	8.476	8.637	8.833
60	88.02	17.715	12.208	12.437	12.719
75	110.	27.65	....	....	....
80	117.36	31.49	21.701	22.11	22.613
90	132.03	39.852	....	....	....
100	146.70	49.2	33.908	34.546	35.332

At the last meeting of the British Association Mr. T. Hawksley, C. E., submitted the following formula and table:

Let v=the velocity of the current in feet per second.

h=the height through which a heavy body must fall to produce the velocity v.

w=the weight in pounds of a cubic foot of the impinging fluid [for atmospheric air averagely about 0.0765 lbs.]

g=32, the co-efficient of gravity.

Then $h=\frac{v^2}{2g}$; and since p the pressure of a fluid striking a plane perpendicularly, and then escaping at right angles to its original path, is that due to twice the height h [Daubuisson's Hydraulics; Rouse's Experiments] we have simply

$$p=\frac{wv^2}{g}$$

$$=(\text{for atmospheric air})\frac{0.0765v^2}{32}$$

$$=\left(\frac{v}{20}\right)^2 \text{very nearly.}$$

From this easily-remembered formula the following Table of Pressures is constructed:

Velocities.		Pressure in Pounds per square foot.
Feet per second.	Miles per hour.	
10	8	0.25
20	13.6	1.00
30	20.4	2.25
40	27.2	4.00
50	34.0	6.25
60	40.8	9.00
70	47.6	12.25
80	54.4	16.00
90	61.2	20.25
100	68.0	25.00
110	74.8	30.25
120	81.6	36.00
130	88.4	42.25
140	95.2	49.00
150	102.0	56.25

In general, only these, the maximum pressures, are required; but sometimes, as in the case of the inclined sail of a windmill or ship, or the roof of a building, the diminished pressure upon a surrace placed obliquely to the *effective* curfent is needed; we have then

$$p=\left(\frac{v \sin \theta}{20}\right)^2$$

in which v=the absolute velocity with which the air strikes the receding plane; and θ=the internal angle made by the obliquely-placed surface and the direction of the impinging wind.

It will be seen that the pressure calculated by Mr. Hawksley exceed Smeaton's and Hagen's. But while the committee appointed to consider the subject, after the destruction of the Tay Bridge, recommend that a maximum wind pressure of 56 lbs. per square foot should be assumed for railway bridges and viaducts, Mr. Hawksley says it is certain that a wind pressure of even 40 lbs. on the square foot is unknown in these islands, because, as may be readily shown, this intensity of pressure would have sufficed to overthrow most of the long-existing factory chimneys, to overset post windmills, and to scatter the greater number of the slighter-built domestic and other structures, which have nevertheless "weathered many a storm," and still remain intact. He considers that for structural calculations a maximum wind pressure of 40 lbs. per square foot may be very safely adopted, notwithstanding some reported anemometrical observations to the contrary. Tredgold also recommends that 40 lbs per square foot should be allowed, and his figures have been adopted by Professor Rankine.

A New Electric Light Regulator.—In order to economise power in electric lighting it is of prime importance to have a regulator which will control the generating mechanism in such a way that the current supplied to the circuit will be just sufficient for the light required, or in other words, for the lamps to be lit. A novel device for this purpose has been exhibited recently at Messrs. Denny and Co.'s Engine Works, Dumbarton, by Mr. Joshua Horton, the Glasgow representative of the British Electric Light Company. It is specially intended for incandescent lights, such as those of Maxim, Swan, and Edison, and it operates so well that whether there are one or thirty lamps in circuit the feeding current is proportioned to the number. This is shown by the appearance of the lights to the eye, or their intensity as taken by the photometer, and also by a current meter. Moreover, the amount of work done by the engine is likewise proportioned to the amount of lamps in circuit. Mr. Horton's plan has been patented, and we are not yet at liberty to give the details; but it is quite independent of the ordinary resistance coils substituted for the lamps.

ECONOMY OF ELECTRIC LIGHTING BY INCANDESCENCE.

Thesis of JOHN W. HOWELL, Class of 1881, Stevens' Institute of Technology.

I.—Economy of the Generator. II.—Economy of the Conductor.
III.—Economy of the Lamps.

In writing this thesis I have endeavored to determine as nearly as I was able the cost of electric lighting by incandescence. Owing to the interest attached to the subject, and the lack of data upon which calculations can be based, I have endeavored to consider the subject in all its details, and have taken every precaution that suggested itself to guard against error.

The data given are sufficient to calculate the number of lamps to be obtained from each indicated horse power in a steam engine; beyond this I have not attempted to go, as my experience is insufficient to enable me to make any further determinations.

EFFICIENCY OR THE GENERATOR.

The generator tested was one of the latest pattern devised by Mr. Edison. It differs from the generators heretofore in general use, principally in the substitution of bars of copper for wires in the armature, which make the resistance of the armature very low and also economizes space, as the bars have a trapezoidal section, and when in position there is only clearance enough to allow for the insulation between them.

In my experiments the field was excited by a current shunted from the main circuit, the relative resistances of the mains and magnet coils determining the amount of energy expended on the magnets, and consequently the intensity of the magnetization and the electro-motive force of the generator.

APPARATUS FOR MEASUREMENT OF THE MECHANICAL ENERGY TRANSMITTED TO THE GENERATOR.

In measuring the energy transmitted to the generator, the dynamometer built by the class of '79 was used. This was carefully standardized by supporting the pendulum in a horizontal position at a point 2 feet from the axis of the shaft, and weighing the pressure of the support upon a platform scale; the weight of the pendulum and support was 183.25; the weight of the support was 12.1; the weight of the pendulum was 171.2 lbs.

This gives us the force acting at the circumference of a pulley of 1 foot radius by multiplying 171.2 by the sine of the angle of deflection. This is a measure of the force transmitted through the gear at the top of the pendulum, and includes, beside the force required to turn the armature in the field of force, the force necessary to overcome the friction of the dynamometer bearing, and also the friction of the armature shaft in its bearings. In order to determine what part of the transmitted energy was lost in overcoming friction, a Prony brake was applied to the pulley of the armature, close beside the belt, while the generator was running. Removing the brushes to be sure no current was generated, we tightened the brake until the pendulum showed the same deflection that it did during the test; we thus made a direct substitution of the Prony brake for the retarding action of the lines of magnetic force upon the armature when the circuit was closed, and the force exerted by the arm of the brake, upon a platform scale reduced to the radius of the pulley, will be the force required to turn the armature in the field of force. Instead of measuring the pressure exerted by one arm of the brake upon a scale, we measured the lifting effort exerted by the other end upon a weight resting upon the scale. We placed a light counterweight upon the other end of the brake, to make the zero reading more definite, and in getting the zero we raised the counterweighted end, and let it down gently, rapping the center of the brake to prevent sticking.

Several readings fixed the zero between 35½ and 35. Running at about the same speed as in the test, and tightening the brake until we got a deflection of 42°, we made several readings on the scale, which varied from 19 to 20½. Using the highest zero reading and the lowest running reading, we get a force of 16½ lbs. acting at a distance of 2 feet from the center of the shaft; this reduced to the radius of the armature pulley gives $16\frac{1}{2}\times\frac{24}{5}=79.2$ for the force acting at the circumference of the armature pulley. If no friction had intervened this force would have been

$$\frac{171.2\times(\text{sine } 42^\circ=66.913)}{125}=91.644 \text{ lbs.},$$

showing a loss of 91.644—79.2=12.444 lbs., or 13½ per cent. of the power transmitted.

This loss of 13½ per cent. is caused by the friction of the dynamometer and the friction of the armature bearings. To get the force actually applied at the circumference of the pulley on the armature shaft, we must determine the friction of the dynamometer bearing alone. To do this we made a wooden brake of the same diameter as the driving pulley on the dynamometer that could run on a 10-inch pulley on the dynamometer shaft, we then clamped the Prony brake upon the dynamo pulley, and also clamped the belt on the dynamo pulley and passed it over the wooden brake. Running under these conditions and tightening the wooden brake on the 10-inch pulley until the pendulum showed a deflection of 42°, we measured the force acting at the circumference of the dynamo pulley and also at the circumference of the dynamometer pulley by the lifting effort of the Prony brake upon the weight on the scale. The object of this arrangement of brakes was to get the friction under the same conditions as those under which we ran the test. To get the zero reading in this case we clamped the Prony on the dynamo pulley, and loosened the wooden brake and counterweighted the other arm of the Prony brake, until the armature turned in its bearings; then letting it come to rest and rapping the bearings of the dynamo and dynamometer, we determined the zero reading to be 33 lbs. Several readings fixed the readings for 42° at 16 lbs., therefore the force acting at the circumference of the dynamo pulley was $(33-16)\times\frac{24}{5}=81.6$, showing a loss of 91.644—81.6 =10.044 lbs., or 10.9 per cent. of the total energy transmitted.

APPARATUS FOR THE MEASUREMENT OF ELECTRICAL ENERGY.

The resistance over which the generator worked consisted of three strands of iron wire in multiple arc, each of which was .104′ in diameter. These were stretched from one gallery of the shop to the other in the open air.

In measuring the resistance of the different parts of the circuit wires were led from the binding posts of the generator to the Wheatstone bridge, then by breaking the connection with the armature and magnet coils, we could measure the resistance of the line, or by breaking the connections with the line and magnets we could measure the resistance of the armature and leaders, or by breaking the connections with the armature and the line we could measure the resistance of the magnet coils.

The electrical energy developed in the circuit was determined by three methods:

1st. By a voltameter, or a copper-depositing cell.

2d. By a calorimeter.

3d. By measuring the electro-motive force and resistance.

FIRST METHOD.

The voltameter consisted of a glass jar large enough to hold six plates of copper, 7″×8″.

These were placed ½″ apart, and held in place by a light wooden frame. They were connected alternately to the positive and negative wires from the generator. This method of arranging the plates brings both sides into action, gives a large area of plate, and makes the resistance of the cell very low and the consequent heating very little. By means of mercury connections the voltameter could be thrown into or out of circuit instantly without breaking the current, and the leaders were so proportioned that throwing it in and out did not alter the resistance of the circuit.

In calculating the current from the weight of copper carried from one set of plates to the other, the weight gained by the negative plates was considered as the weight carried over, and the constant .32456, given by Sprague (Jenkin gives .324) for the amount of copper in milligrams carried over in one second by a current of one Weber. Before making the test, the current was passed through the voltameter for some time, in a direction opposite to that in which it was passed during the test, to insure that the copper carried over during the test was copper that had been deposited before, otherwise energy may be lost in separating the copper from the positive plate.

SECOND METHOD.

In determining the electrical energy by the second method, a calorimeter was used which consisted of a cylindrical vessel of galvanized iron encased in a wooden jacket, and so supported as to leave an air space of about ½ an inch on all sides between the calorimeter and the jacket. This prevented any great conduction of heat from the calorimeter to external objects; still some heat must be wasted in heating the calorimeter and the surface it rests upon.

To determine the amount of heat thus wasted 55 lbs of water was put in the calorimeter, and its temperature carefully determined it was 19.85°C. A large pail of water was then heated to 54.3°C, and 18¾ lbs. were poured into the calorimeter. This made the weight of water in the calorimeter about the same as was used in the test, and the same part of the calorimeter was heated in each case, the final temperature of the water being 28.50°C, the range of temperature used in the test was included in this range. The heat contained in the water poured into the calorimeter may be represented by $18.75 \times 26.2 = 491.25$. Of this $55 \times 8.65 = 475.75$ went to raise the temperature of the water in the calorimeter, and the remainder 155 must have been imparted to the calorimeter. As the range of temperature in the calorimeter was 8.65°, 1.78 of these units were required to raise the temperature 1°, or the same amount of heat was used in heating the calorimeter as would be rerequired to raise 1.78 lbs. of water through the same range of temperature; therefore the proper correction may be applied by adding 1.78 lbs. to the weight of water in the calorimeter.

To measure the heating effect of the current, a coil of copper wire was put into the calorimeter, the resistance of which was exactly .1$\frac{1}{10}$ Ohm, at 74° F. The chief source of error in a calorimeter test of this kind is the tendency of the current to pass from one part of the wire to another through the water, instead of passing through the wire. This in itself is not a source of error if we measure the resistance of the coil in the water, but in so passing, it may carry metal from one part of the wire to another, and the energy so used cannot be calculated, and is lost; to obviate this difficulty distilled water was used, the resistance of which is much higher than ordinary water. The resistance of the coil measured in the water did not differ perceptibly from its resistance in the air, and at the close of the test no evidence of copper having been carried from one part to the other was discernable. To determine the range of temperature during the test, a Fahrenheit thermometer was used that was graduated to fifths of degrees, but the graduation was so plain that twentieths of a degree could easily be read. In order to be certain that the temperature of the water was uniform throughout a pump was placed in the center of the calorimeter, which consisted simply of a copper tube about 1¾″ in diameter, its bottom was ½″ above the bottom of the calorimeter and contained a valve opening downward; the piston also carried a valve opening downward. The water in the calorimeter covered the top of the tube, and by this means the water was taken from the surface when it is warmest, and carried to the bottom, where it is coldest. The circulation thus obtained was very perfect, as shown by some ink drops put in the pump barrel.

THIRD METHOD.

In determining the electrical energy by he third method, the electro-motive forcet was measured between the binding posts of the generator, by means of a Thomson high-resistance galvanometer. As a standard of electro-motive force, Latimer Clark cells were used, four of which were made up new for the purpose. These agreed with each other very closely, and in using them they were connected in series, thus getting their combined effect, and averaging their errors.

In using them they were allowed to charge a condenser, and the condenser was then discharged through the galvanometer.

The deflection produced is an accurate measure of the current flowing through the galvanometer and consequently of the charge held by the condenser, which depends upon the electro-motive force of the terminals connected with the condenser. To connect the condenser alternately with the cells and the galvanometer, a simple switch was used by which the change could be made instantly. In making the test part of the condenser of $.2\frac{8}{10}$ microfarad capacity wire used and four standard cells in series. The damping magnet of the galvanometer was then adjusted until the discharge of the condenser produced a deflection of 291 divisions, as the electromotive force of the cell is 1,456 volts and four in series were used, the deflection corresponding to one volt was $\frac{291}{1.456\times4}$ $=50$. The instrument being standarized in this way, the liability to error was very small; in use, however, $\frac{9}{10}$ of the current was shunted from the galvanometer, only allowing $\frac{1}{10}$ to pass through, thus getting five deflections to a volt.

The ends of all wires dipping into mercury were amalgamated with mercurous nitrate, which made the connections very perfect.

In measuring the resistances of the armature and of the armature and leaders, the Wheatstone's bridge was used, and Thomson's reflecting galvanometer in place of the small galvanometer usually employed. The resistance of the armature mains and leaders was between .17 and .18 Ohm. When the bridge indicated .17 the galvanometer showed a deflection of 29.5 divisions; when it indicated .18 the galvanometer showed an opposite deflection of 45. From this we get the resistance of the armature mains and leaders, .17395 Ohm.

The main alone measured .14460, leaving for the resistance of the armature and leaders to the binding parts .029 Ohm.

Leading wires being clamped on the commutator the resistance measured in several positions was .16207. These leaders measured .14604, leaving for the resistance of the armature alone .016 Ohm.

The resistance of the field magnet coils was 37. Ohms.

TEST BY VOLTAMETER.

Before making the test the generator was run for some time to allow the circuit to heat up, and the resistance of the line measured from time to time until it was found to remain constant. The voltameter was then introduced into the circuit and allowed to remain fifteen minutes.

During this time the speed of the dynamometer was determined for ten minutes, and the average speed computed.

The deflection of the pendulum was observed every three minutes and the average taken, although the variation was only one degree. At the end of the test the circuit was broken and the resistance again measured, and it was found not to have changed perceptibly.

The plates were then removed, washed in water, then in alcohol, and dried in a gentle heat. They were then weighed carefully.

DATA OBTAINED FROM THE TEST.

Weight of copper gained by negative plates =24,465 m. g.
Time of test = 15 minutes.
Weight gained per second = 27,183 m. g.
Average speed of dynamometer = 400.5 rev. per min.
Average deflection of pendulum=42° 20′.
Resistance of iron wire = .76 Ohm.
Resistance of iron wires and magnet coils in multiple arc = .744 Ohm.
Total resistance of circuit = .744+.029= .773 Ohm.
Internal resistance of armature = .016 Ohm.

RESULTS OBTAINED FROM DATA.

Value of current in webers = $\frac{27.183}{.32456}=$ 83.753.
Electrical energy $(83.753)^2\times.773\times44.24=$ 239880.726 ft. lbs. per minute.
Energy indicated by dynamometer 171.2 $\times(\sin 42°=.67344)\times4505\times6.2832$ $=290125.54$ ft. lbs. per minute.
Friction of dynamometer and generator $290125.54\times.135=39166.9479$ ft. lbs. per minute.
Energy used in turning armature in field of force $290125.54\times855=250958.59$ ft. lbs. per minute.
Friction of dynamometer alone=290125.5 $\times.109=31623.68$ ft. lbs. per minute.
Energy actually applied to armature pulley $290125.54\times.891=258501.96$ ft lbs. per min.

Of the total electrical energy 239880.7 $\frac{.016}{.773}=4965.189$ appeared in the armature, $\frac{.744}{.773\times49.68}\times239880.726=4647.39$ in the magnet coils, and 230268.176 ft. lbs. per minute in the external circuit.

The efficiency of the generator is the ratio of the energy required to turn the armature in the magnetic field, to the total electrical energy developed $= \frac{239880.726}{250958.59} = .955$.

The commercial efficiency is the ratio of the energy required to drive the machine (including friction) to the electrical energy which appears in the external circuit $= \frac{230268.169}{258501.96} = .8608$.

TEST BY MEANS OF THE CALORIMETER.

As in the voltametric test the generator was first run until the circuit was thoroughly heated, and the same care was taken to determine the speed and deflection of the dynamometer. When the calorimeter was thrown into the circuit an approximately equal resistance was thrown out so as not to change the total resistance too much. At the end of the test the resistance of the circuit was measured carefully as soon as the circuit was broken and before the wires became cooled.

DATA OBTAINED FROM THIS TEST.

Water in calorimeter = 77 lbs.
Connection for waste heat = 1.78 lbs.
Range of temperature = 79° − 69.8° = 9.2°F.
Specific heat for this range = 1.0015.
Average speed of dynamometer = 394 rev. per min.
Average deflection of pendulum = 43° 24′ (sin = .68709).
Time of tests = 16 minutes.
Resistance of iron wires and calorimeter coil = .68 Ohm.
This and magnet coil in multiple arc = .667 Ohm.
Total resistance of circuit .667 + .029 = .696.
Resistance of calorimeter coil = .1 Ohm.

RESULTS OBTAINED FROM THESE DATA.

Energy developed in calorimeter =

$$\frac{78118 \times 1.0015 \times 9.2 \times 772}{16} = 35022.897 \text{ ft.lbs.}$$

per minute.

Total electrical energy

35022.897 × 6.96 = 243759.36 ft. lbs. per minute.

Energy indicated by dynamometer =

$$171.2 \times .68709 \times 894 \times 6.2832 = 291201.46 \text{ ft. lbs. per min.}$$

Energy used in turning armature in field of force

$$291201.46 \times .865 = 251889.265 \text{ ft. lbs. per min.}$$

Energy actually applied to armature pulley

$$291201.46 \times .891 = 259460.5 \text{ ft. lbs. per min.}$$

Of the electrical energy

$$243759.36 \times \frac{.016}{.696} = 5603.66$$

appeared in the armature

$$243759.36 \times \frac{.667}{.669 \times 54.41} = 4215.89$$

in the magnet coils; and 233939.81 ft. lbs. per minute appeared outside.

$$\text{Efficiency} = \frac{243759363}{251889.265} = 967.$$

$$\text{Commercial efficiency} = \frac{233939.81}{259460.5} = .901.$$

TEST BY MEASUREMENT OF THE ELECTRO-MOTIVE FORCE AND RESISTANCE.

In this test the electro-motive force was measured between the binding posts of the generator, and the external resistance was measured between the same points.

The deflection and speed of the dynamometer were measured at the same time, the electro-motive force was observed and the resistance was measured just before and after these observations and was the same in both cases.

DATA OBTAINED FROM THIS TEST.

Electro-motive force = 53 volts.
Resistance of circuit (external) .64 Ohm.
Resistance between binding posts .629.
Average speed of dynamometer, 355 rev. per min.
Average deflection, 42° (nat.sine = .66913).
Total resistance of circuit, .658.

RESULTS OBTAINED FROM THESE DATA.

Energy developed in external circuit

$$\frac{(53^2)}{629} \times 44.24 = 197567.43 \text{ ft. lbs. per min.}$$

Total electrical energy

$$197567.43 \times \frac{.658}{.629} = 206673.0295 \text{ ft. lbs. per min.}$$

Energy in armature

$$206673.029 \times \frac{.016}{.658} = 5025.5.$$

Energy in magnet coils

$\frac{(53^2)}{37} \times 44.24 = 3346.667$ ft. lbs. per min.

Energy in external circuit 198300.88 ft. lbs. per min.

Energy indicated by dynamometer

$171.2 \times .66913 \times 355 \times 62332 =$
2553 + 9.04 ft. lbs. per min.

Energy used in turning armature in field of force

$255519.04 \times .865 =$
221023.97 ft. lbs. per min.

Energy actually applied to armature pulley

$255519.04 \times .891 =$
227667.47 ft. lbs. per min.

$$\text{Efficiency} = \frac{206673.0295}{221023.97} = .935.$$

$$\text{Commercial efficiency} = \frac{198300.88}{227667.47} = .87.$$

Average efficiency, .951.
Average commercial efficiency, .887.

ECONOMY OF THE CONDUCTORS.

The economy of the conductors which convey the electricity from the generator to the lamps may be considered under two heads: first, the efficiency of the material, second, the efficiency of its dimensions.

The efficiency of any material is determined by its price and conductivity as compared with other materials. The two materials most commonly used for conductors are copper and iron. The present price of copper is about seven times the price of iron and its conductivity is about six times as great; thus the actual cost of a line of copper wire of a given conductivity is one-sixth greater than iron wire of the same conductivity. Copper wire, however, is much more uniform than iron wire; it is free from cinder streaks that are so common to iron wire, and is much more pliable and less bulky, and therefore less difficult to handle. For electric-light mains, which have to be frequently tapped, copper wire seems to be preferable to iron wire.

2D. THE EFFICIENCY OF DIMENSIONS.

This is determined by the cost of the conductor and the loss of energy in the conductor. As the energy developed in different parts of the circuit varies directly as the resistance of these parts, some energy must appear in the conductors. This energy appears as heat, and is lost.

The most efficient dimensions of the conductors depend upon the amount of energy to be transmitted and the distance which it is to be transmitted.

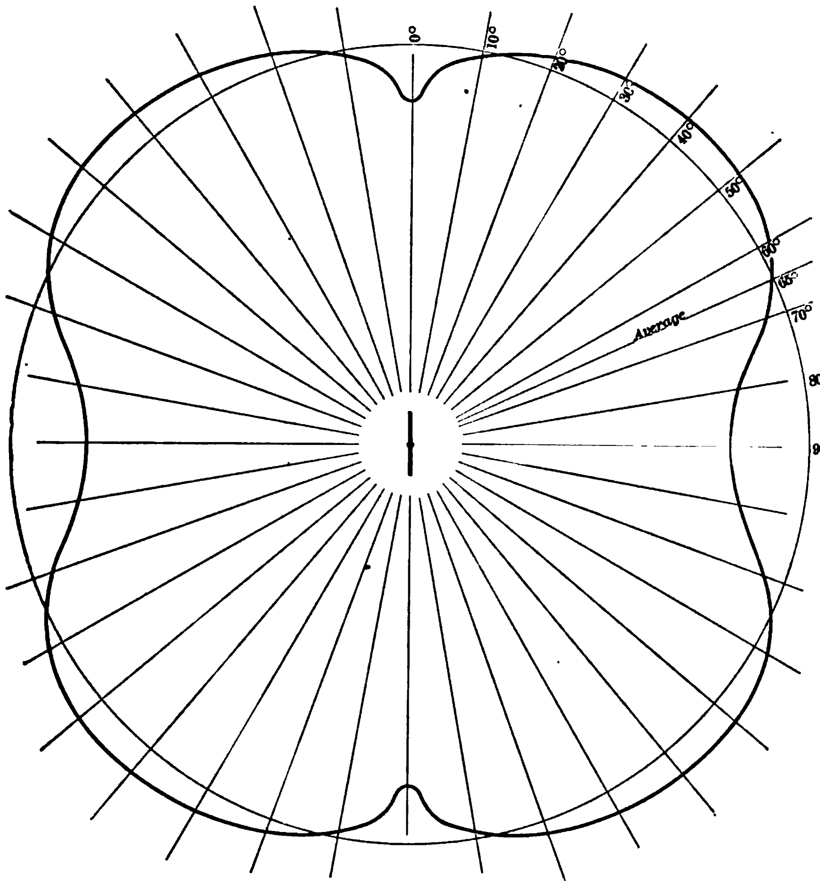
To secure maximum efficiency, therefore, we would have to calculate the most efficient size under all conditions as to number of lamps and distances. Knowing, however, the conditions most usually met in practice, we can determine that loss of energy in the conductors, which is usually most efficient and expressing this loss as a percentage of the total energy transmitted, calculate the size of our conductors upon this basis by making the resistance of the conductors the same percentage of the total resistance of the circuit, as the loss of energy allowed is of the total energy transmitted.

Thus, when we wish to calculate the dimensions of our conductors necessary to convey the current to a given number of lamps a given distance, allowing a loss of $\frac{1}{n}$ of the total energy, we must determine the resistance of our lamps and make the resistance of our conductors $\frac{1}{n-1}$ part of the resistance of the lamps.

Thus we see that the cost of the conductors necessary to carry the current for a given number of lamps a given distance varies inversely as the resistance of the lamps, and although we can make a high or a low resistance lamp of the same economy, it will cost less to convey the current to a given number of high-resistance lamps a given distance, than it will to convey the current to the same number of low resistance lamps the same distance.

ECONOMY OF THE LAMPS.

The economy of the lamps is determined by the energy consumed and the amount of light produced; in determing the energy consumed in the lamps, the electro-motive force was measured between the terminals of the lamps, and also the resistance, and the energy determined in foot pounds per minute by the formula $\frac{e^2}{R}$ 44.24. In measuring the electro-motive force the same arrangements were used as in determing the electro-motive force of the generator, but the damping magnet was adjusted to give three units of deflection to a volt instead of five. To measure the resistance of the lamps when burning, the current was divided into two parts, one part was passed through the lamp and the other through a variable resistance, when both were passed through a differential galvanometer, but in opposite directions; when the current was the same in both branches, the needle of the galvanometer of average illumination was first determined for the lamp used, which was the Edison lamp. To determine this angle, the candle power was measured every 10° through a quadrant, and the candle power observed laid off on a suitable scale on lines radiated from a point. A curve was drawn through the points thus determined,



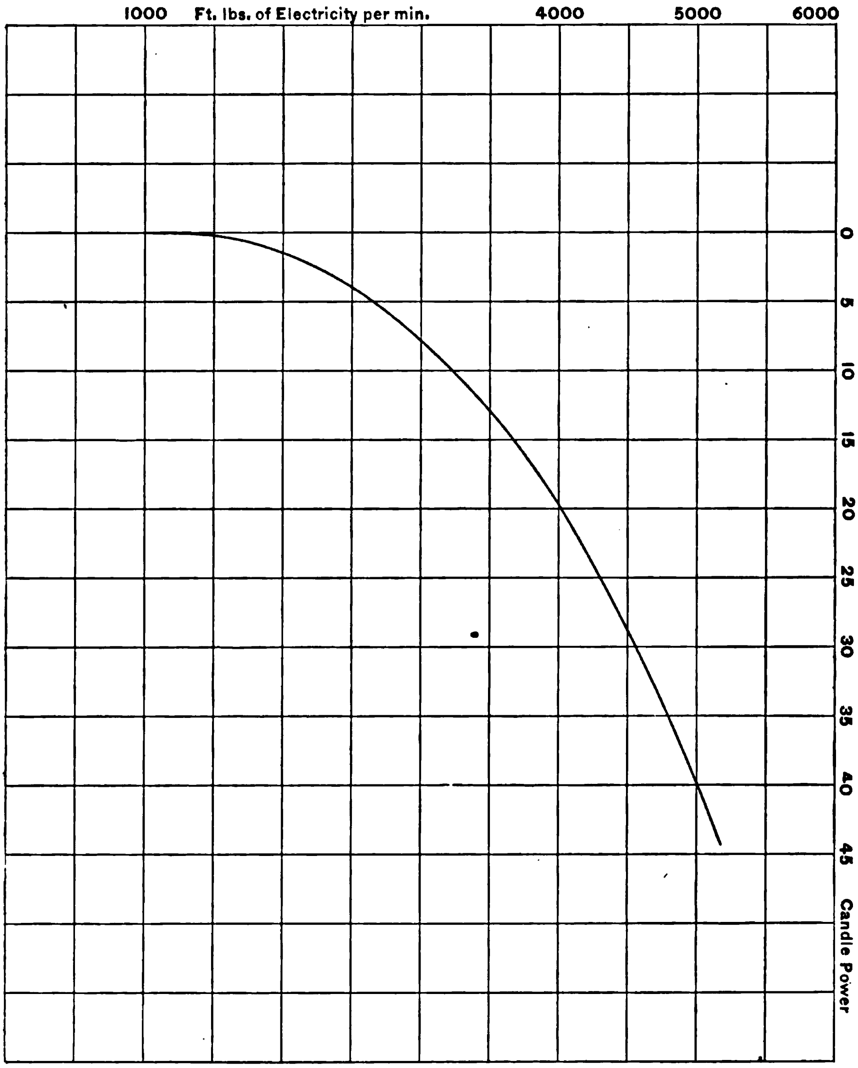
CURVE SHOWING ILLUMINATION OF EDISON'S LAMP IN A HORIZONTAL PLANE.

would indicate zero. As the electro-motive forces of the two branches were equal, their currents were equal, when their resistances were equal, so by altering the variable resistance until the needle came to zero, and measuring the variable resistance we thus determined the resistance of the lamp while it was burning. This variable resistance was measured each time before it cooled.

As the light given out in a horizontal plane varies at different angles, the angle and the four quadrants being made symmetrical, its area was determined and a circle of equal area drawn about the point from which the lines radiate. The points where this circle cut the curve determine the angle at which the candle power is the same that it would be if the light wereevenly distributed.

Having determined the angular position of these points with reference to the plane of the carbon, all measurements were made with the axis of the photometer in this angle.

To insure that the lamp was in this position, it was twisted until the shadow of the carbon fell on the center of the disc and then turned through an angle of 65°, which the curve shows to be the proper angle. All measurements of lamps were made at the angle of equal illumination.



CURVE SHOWING RELATION BETWEEN ECONOMY AND INCANDESCENCE.

In order to determine the economy of a lamp at different degrees of incandescence, an Edison lamp was measured at intensities ranging from a dull red to 40 candle power, and the results plotted in a curve show a rapid rise in economy as the candle power increases. While the economy of a lamp increases with incandescence, its life shortens, but as I have had neither time nor opportunities for life tests, I cannot give data for life at various degrees of incandescence.

Mr. Edison's standard of illumination has been 16 candle power, and his aim has been to produce a lamp that will give good economy and a reasonable life at that candle power.

To determine the energy consumed by these lamps when burning at their normal candle power, five lamps, as made at pre sent by Mr. Edison, were tested with the following results:

TABLE SHOWING ENERGY CONSUMED BY EDISON LAMPS.

	Candle Power.	Volts.	Ohms.	Foot-pounds of Electricity per minute.
1	16	98.66	135.5	3178-08
2	16	98.66	142.5	3021-91
3	16	99.	140.5	3107-41
4	16	98.	148.5	2861-15
5	16	99.33	131.5	3319-32

Showing an average of 3,097-564 ft. lbs. of electricity per minute, or 10.65 lamps per h. p. of electricity, giving 170 candles per h. p.

Mr. Edison gets 10.65 lamps per horse power of electricity, but as he allows a loss of 10% of the electrical energy used in the lamps upon the conductors, he gets 9.68 lamps for each h. p. of electricity generated. As the average commercial efficiency of this generator is .887, this gives him 8.58 lamps per dynamometrical h. p.

The report of the Board of Commissioners of the Millers' Exhibition, held in Cincinnati just one year ago, gives the results of the trial of three modern steam engines.

These results show an average for the three engines of .878 of the indicated power converted into useful work; using this factor for the conversion of dynamometrical into indicated horse power, we find that Mr. Edison gets 7.62 lamps per indicated horse power.

THE INTER-OCEAN CANAL.

By W. E. DAUCHY, C.E.

From Papers of the Pi Eta Scientific Society.

The subject of an inter-oceanic canal across the American Isthmus is by no means a new one. Ever since Balboa made his way across this narrow strip of land, and discovered the Pacific Ocean lying beyond, the possibility of joining the two oceans by a navigable water-way has been more or less talked of.

As the subject is being brought prominently before the public at the present time, I propose to give you a brief summary of the work that has been done in making explorations and surveys, together with a few remarks on M. De Lesseps' proposed canal.

At first it may seem strange that so little is known of the American Isthmus, as it was there that the first settlements were made upon the continent, but when we consider the character of the country, it is not so much to be wondered at. Nature has here done all she can to defy exploration. The whole surface of the country is covered with a dense growth of forest, which is so thickly interwoven with vines and vegetation of every character, that it is in many places impossible for a man to walk through it without cutting his way at every step. These forests are the abodes of fevers, which are disastrous to explorers. Vegetation has such a rapid growth that even though a path be cut through the forest, unless it is continually used and kept trimmed, it is in a few weeks so covered with [a new growth as not to be discernible. As a result, a knowledge of the country away from the sea-coast and the usual routes of travel, has been difficult to obtain.

During the past thirty years numerous explorations and surveys have been made of all feasible canal routes from the Isthmus of Tehuantepec to the Napipi River. This work has been carried on by the United States Government, by foreign Governments, and by private citizens. Commencing with the work done by the Government of the United States, the following is a list of the surveys and reconnoissances that have been made, taking them in their geographical order, from the north and west to the south and east:

I. An instrumental reconnoissance of the Isthmus of Tehuantepec by Capt. R. W. Schufeldt, U. S. N., in 1872. This route was found to be 144 miles in length, and the number of locks required 140.

II. An examination, survey and definite location of a canal route from the vicinity of Greytown, via Lake Nicaragua and the Rio del Medio and Rio Grande, to Brito, made by Commander E. P. Lull, U. S. N., in 1872-3, with some preliminary work by Commander Chester Hatfield, U. S. N., in 1872. The length of the actual canal required by this route was found to be 67.75 miles. Slack water navigation by means of dams in the bed of the San Juan River for 63 miles, and lake navigation for 56.5 miles. This plan involves the construction of four dams, with an average height of 29.5 feet, and an aggregate length of 1,320 yards, and of twenty locks of an average lift of 10.28 feet. It also requires the construction of two harbors at the termini, to insure a smooth and safe entrance and exit to and from the canal.

III. An examination, survey and definite location of a canal route from Navy Bay to Panama, by Commander E. P. Lull, U. S. N., in 1875. This route follows the Chagres River to Matachin, and from there follows the line of the Panama Railroad to Panama, crossing the divide by the same pass through which the railroad runs. This is the route by which M. De Lesseps proposes to build his canal, and of which I shall say more further on.

IV. Examination and surveys of the San Blas route by Commanders T. O. Selfridge and E. P. Lull, U. S. N. In 1870 Selfridge made a survey from the Gulf of San Blas on the Atlantic side towards the River Chepo. And in 1875 Lull, commencing on the Pacific side, made an examination of the River Chepo, and from there towards the Gulf of San Blas.

V. Several tentative instrumental lines were run in 1871 by parties under the direction of Commander Selfridge, in the vicinity of Caldonia Bay across the Cordilleras to the waters of the Sucubti and Morti Rivers, tributaries to the Chuchanqui. A line from the southern extremity of Caldonia Bay was found to cross the divide at the elevation of 1,259 feet, and struck the bed of the Sucubti at a height of 553 feet. A line from the northern extremity of Caldonia Bay up the valley of the Sassardi and across the divide to the Marti, crossed at an altitude of 1,148 feet, and no indications of any pass was discovered under 1,000 feet.

VI. A barometrical reconnoissance was also made in 1871 by Commander Selfridge of the De Puydt route. The Atrata and Teyter Rivers to be connncted by way of the Tanda River. The exact line advocated by De Puydt was followed for thirty miles. At this distance an elevation of 638 feet was reached, and the mountains of the divide were plainly visible beyond. The observations were taken with great care. Three mercurial barometers were used, one at the sea-level was observed at short intervals during the whole work; the other two were carried by the party, and bench marks were established, one barometer remaining at each bench until the other had reached the next, and until sets of different observations had been obtained.

VII. Tentative instrumental lines were run in 1871 by parties under the direction of Commander Selfridge from the east coast, by the Atrato, Cacarica, Peranchita Rivers, and from the west coast via the Tuyra and Cue Rivers across the divide. These lines crossed the divide at an elevation of 712 feet.

VIII. An instrumental examination of the Truando was made by Lieutenant Michler, U. S. A., and Lieutenant Craver, U. S. N., in 1856-7, and by them was reported upon as unfavorable.

IX. An instrumental reconnoissance of the Napipi and Cuia Rivers was made by parties under the direction of Commander Selfridge in 1871 and 1873. Also a reconnoissance of the Atrato River to the town of Quibdo.

X. Tentative examinations and a definite location of a route by way of the Napipi and Daguado Rivers were made in 1875 by Lieutenant Frederick Collins, U. S. N.

Of the above work done by the United States Government, actual instrumental locations were made at only three points, Nicaragua, Panama, and the Napipi. The tentative lines in other places were only carried sufficiently far to demonstrate their impractibility—or manifest inferiority.

Seven parties have been sent to the Isthmus at different times by Frederick M. Kelly of New York, who has spent a fortune and devoted years of his life to the study of the subject of a canal across the Isthmus.

The first party was sent out by Mr. Kelly in 1852, and was in charge of John C. Trautwine of Philadelphia. Entering the Gulf of Darien, Mr. Trautwine ascended the Atrata River 220 miles to Quibdo, and from thence advanced to the Raspadura Isthmus. He descended the San Juan to the Pacific and thus completed a careful survey from ocean to ocean 360 miles in length. Retracing his steps to Quibdo, he examined several passes leading to the Pacific by the Napipi, Beando, Pato and other rivers, and returned to New York and reported against the route.

In 1853 Mr. Kelly fitted out two engineering parties, and placed one in charge of Noah B. Porter, and the other in charge of Colonel James C. Lane, and instructed them to follow up Mr. Trautwine's survey to Quibdo, and from thence examine other passes leading to the Pacific higher up or lower down the Atrato at that place. They returned and reported against the route.

In 1854 Mr. Kelly sent out a fourth party in charge of Colonel Lane with instructions to ascend the Atrato to its confluence with the Truando, and from there to level across the country to Kelly's inlet on the Pacific. This survey proved a failure as the whole party were so reduced by sickness contracted at Aspinwall that Colonel Lane with but one man capable of doing duty could only reach the foot of the Cordilleras on the Atlantic side.

The following year Mr. Kelly sent out a fifth party under the charge of Captain William Kennish. This party crossed the Isthmus of Panama and commenced work from the Pacific side, at about 6° 57′ 32″ north latitude. Mr. Kennish succeeded in finding a feasible route for a canal 200 feet in width, 30 feet deep and including a tunnel through the Cordilleras.

In 1863 Mr. Kelly, assisted by Mr. Cyrus Butler and Mr. Luke T. Merrill of New York sent out Mr. Norman Rude to examine the San Blas route. Mr. Rude ran a barometrical line for the purpose of obtaining approximate heights and distances only. This resulting favorably, Mr. Kelly in 1864 sent out his seventh party, in charge of Mr. A. McDougall, to run a line of chains and levels. Commencing on the Pacific side they ascended the Bayano River to the great bend, and from there via the Mamoni, crossed the mountains to within three miles of the Gulf of San Blas on the Atlantic, where they were stopped by the Indians, and had to turn back. They reported the distance about thirty miles from ocean to ocean.

Several surveys have been made by English and French engineers. During the years 1877 and 1878 a large party of French engineers, in charge of Lieutenant Lucien N. B. Wyse, made several careful surveys between the Gulf of San Miguel and the Atlantic. They also examined the Panama and other routes.

In 1843 the French Government sent out Messrs. Garella and Courtenes to make examinations. And in 1865 M. de la Charme surveyed a line from the Gulf of Darien to the Gulf of San Miguel, via the River Tuira.

In the same year M. De Puydt, a French engineer, reported the discovery of a favorable route from the port of Escondido to the Tuira, and thence to the Gulf of San Miguel. This route was afterwards found by Commander Selfridge, U. S. N., to be impracticable. As early as 1827 explorations were made by Floyd and Falmark, engineers who were under the orders of General Bolivar.

These surveys and explorations have given the world enough general knowledge of the possible routes, to enable it to decide upon the most feasible one. And it was ostensibly for this purpose that the Inter-National Canal Congress convened in Paris in May, 1879. During the proceedings of that body it soon became evident that a choice of routes was not to be made according to the merits of each. And M. De Lesseps, who was president of the congress, and who had never been to the Isthmus, and personally knew nothing about the route he was advocating, succeeded in forcing a decision in favor of the Panama route, and in fovor of constructing a tide-water canal without locks. The American representatives all declined to vote, on the ground that only able engineers can form an opinion after careful study of what is actually possible, and what is relatively economical to the construction of a ship canal.

In 1878, when Lieutenant Lucien N. B. Wyse was in the United States of Columbia, he went to Bogota and made a contract with the Columbian Government in the name of the Civil International Canal Society, of which the following are the principal provisions:

ARTICLE 1st. Provides that the Civil International Canal Society shall have the exclusive privilege for the construction of a canal across the territory of the United States of Columbia, between the two oceans. This concession is made under the following conditions.

1. The duration of the privilege shall be for ninety-nine years, reckoned from the day on which the canal shall be opened wholly or partially to the public service.

2. The Government of the public cannot construct by itself or concede to any company or individual the right to construct another canal across Columbian territory which shall put in communication the two oceans. If the grantees wish to construct a railroad as an auxiliary to the canal, the Government (save existing rights) cannot construct by itself, or concede to any other company or individual the right to establish another inter-oceanic railroad during the time conceded for the construction and use of the canal.

3. The necessary studies of the ground and route for the line of the canal, shall be made at the cost of the granteesby an international commission of engineers, in which two Columbian engineers shall take part. The commission shall determine the general route of the canal and inform the Columbian Government of the same, at the latest in 1881, unless extreme necessity, clearly proven, shall prevent.

4. The grantees shall then have a period of two years to form a universal stock company, which shall take charge of the enterprise.

5. The canal shall be finished and placed at the service of the public during the following twelve years, counting from the time of the organization of the company to undertake its construction. But the executive power is authorized to grant a farther maximum term of six years, if, in an extreme case beyond the control of the company, and after one-third part of the canal is built, they shall recognize the impossibility of finishing the work in the said twelve years.

6. The canal shall have the length, depth and all other conditions necessary in order that sailing vessels and steamers of 140 meters in length, a maximum beam of 16 meters, and drawing 8 meters of water shall, with lowered topmasts, be able to pass the canal.

7. All unoccupied lands which may be necessary for the route of the canal, the ports, stations, wharves, moorings, warehouses, and in general for the construction of the canal and service of the same, as well as for the railroad, should it be convenient to build it, shall be considered free to the grantees. These lands shall revert to the government of the republic with the canal and railroad, at the termination of the ninety-nine years.

8. There is also conceded for the use of the canal a strip of land two hundred meters wide on both sides of its banks throughout its whole length.

9. The grantees shall have the right to demand the expropriation by the government, according to the legal formalities in such cases, of all private lands through which the canal shall pass.

10. The grantees may establish and operate the telegraphic lines which they may consider useful as auxiliaries to the canal.

ART. 2d. Provides that within the term of twelve months, reckoned from the time in which the commission shall have presented the result of it definite studies, the grantees will deposit in the bank or banks of London, which the executive power may designate, the sum of seven hundred and fifty thousand francs as a security for the execution of the work.

ART. 3d. Provides that should the route for the construction of the canal, from one ocean to the other, pass north or west of the imaginary straight line which joins the cape Tiburon with Garachine Point, the grantees must arrange amicably with the Panama railroad company, or pay an indemnity which shall be established by the terms of the law which approves the contracts made between that company and the government of the republic.

ART. 4th. Provides that the government of the republic shall bestow upon the grantees 500,000 hectares of unoccupied public lands, with the mines they may contain. The public lands lying along the margin of the canal to be divided into lots of a thousand or two thousand hectares, and the grantees having each alternate lot.

Art. 5th. Provides that the waters of the canal and the ports of the termini shall be neutral, and in case of war between other nations, or between one or other of these and Columbia, the transit of the canal shall not be interrupted.

Art. 6th. Provides that the entrance of the canal shall be vigorously prohibited to the war vessels of those nations which are at war with one another, and whose destination manifests their intention to take part in hostilities.

Arts. 7th, 9th, 10th and 11th provide that no taxes or duties of any kind whatsoever shall be imposed upon any material used in the construction and use of the canal or upon any of their property, or upon the tonnage passing through the canal.

Art. 14th. Provides that all tolls shall be levied without exception or favor upon all ships in identical conditions; also that the principal tolls which shall be levied upon vessels shall not exceed the rate of ten francs for each cubic meter resulting from the multiplication of the principal dimensions of the submerged portions of the ship in transit, and that special tolls for navigation shall be reduced in proportion to the excess, when the net profits derived from it shall exceed 12 per cent. upon the capital employed in the enterprise.

Art. 15th. Provides that the government of the republic, in return for the privileges granted shall enjoy a participation equal to five per cent. of the gross product which shall accrue to the enterprise, according to the tariff which shall be fixed by the company.

After the meeting of the canal congress in Paris, M. De Lesseps organized a company for the construction of the canal, and obtained from the Civil International Canal Society the right granted them by the Wyse contract, for which the canal society received 1,000 shares of the stock of the canal company.

M. De Lesseps went to the Isthmus in December, 1879, and on the first day of January, 1880, fired a blast on the route of the proposed canal, and from that moment considered the work on his canal to have been started.

On his return from the Isthmus, M. De Lesseps came to this country and made strenuous efforts to induce capitalists to subscribe for shares in his canal company, but the whole affair has savored so much of an immense stock-jobbing operation, that he has failed to obtain that aid which he hoped to get from the United States.

The preliminary examinations of the work to be done, which were made when M. De Lesseps was on the Isthmus, were made in a hurried manner, and difficulties and obstacles have been slurred over. The most important one, perhaps, is the question of drainage. By referring to the accompanying map, on which is shown the route of the canal chosen by M. De Lesseps, you will see that it follows the course of the Chagres river for half the distance across the Isthmus, crossing and recrossing that stream several times. The Chagres river drains the whole Atlantic slope of the Isthmus for miles, and a canal at the sea level will, of course, take the place of the river to carry off the drainage of the country. M. De Lesseps proposes to govern this question of drainage by building a great dam in the vicinity of Cruces and there storing the water during the time of floods.

To a person unacquainted with the nature of the country, this solution of the drainage question may seem very plausible, but to one who has witnessed the floods that take place almost every year, at the close of the rainy season, it is hardly satisfactory.

The Chagres river has a great many tributaries entering it below the proposed location of the dam. Towards the latter part of the rainy season (which lasts from about the first of June to about the first of January), each of these tributaries becomes greatly swollen, pouring into the Chagres its share of water, drift, and sediment, and the latter river becomes a torrent, inundating its banks, and in some places flooding the country for miles.

During the month of November, 1876, one of these floods occurred raising the Chagres river between thirty and forty feet. At that time the river was so swollen that it stopped all traffic over the Panama Railroad for a week. The line of the railroad follows the Chagres river from Gatun to Matachin. At the time of this flood a person could go the majority of the distance between the two places in a canoe right over the track. The water was up over the telegraph wires along the road, stopping all communication by telegraph for five days. Such floods as this occur nearly every year.

The route of the canal crosses the summit at Culebra through the same pass that the Panama Railroad now runs. The summit of the railroad is 280 feet above the sea level, and at that point the road runs through a cutting 24 feet deep, making the summit of the pass about 300 feet above the sea.

Another question to be considered is whether the amount of tonnage that will pass through the canal is such as M. De Lesseps claims. I think it is doubtful whether sailing vessels will use a canal, built by the Panama route, to the extent that is usually calculated. There are three things they will have to contend with: 1st. Prevalence of calms in Panama bay. 2d. Prevalence of calms at certain seasons in the Caribbean sea, and 3d. The existence of currents in the Caribbean sea. The two latter acting together are great sources of annoyance to sailing vessels trying to make the harbor of Aspinwall.

During the Summer of 1878, while I was on the Isthmus, we were looking anxiously for a vessel which was on her way from Boston to Aspinwall, with a cargo of ice, as the supply of that article was entirely exhausted. The vessel was ninety-one days making the voyage, and was sighted one morning at Aspinwall, and if the light breeze which was blowing at the time had continued, she could have made the harbor in a few hours. But what breeze there was died out, and the current which flows northeast along the coast, at that point, drifted her out to sea again, and it was nearly two weeks before she made the harbor.

In the month of October, 1878, the steamship "Colon," while making the voyage from New York to Aspinwall, broke the crank pin of her engine when within 500 miles of Aspinwall. She proceeded on her voyage under sail, making very good progress until one evening when she was about sixty miles from Aspinwall, the wind died out. The next day at noon, when the captain took an observation, he found the steamer was over 120 miles from Aspinwall, and she did not reach that place for several days, when the engineer had fitted up another crank pin, and she went in by steam.

The so-called harbor at Aspinwall, or, as it is sometimes called, Navy bay, or the bay of Limon, is in reality no harbor at all, but an open roadstead, and at certain seasons is subject to storms which come from the north, and at such times the harbor is no protection to vessels at anchor, or laying at the wharves.

When these storms occur all steamers put to sea to prevent going ashore, and what sailing vessels are in the harbor put out all the anchors they have, and do the best they can to ride out the storm, but the result usually is, if the storm be a severe one, that the majority of them are wrecked. To make the harbor secure, as it must of necessity be, to be used as the terminus of the canal, a breakwater will have to be built, narrowing the mouth of the bay. The bay of Panama is a good harbor in every respect. Tide-locks will, of course, have to be built at each terminus. The difference in elevation between high and low tide is about 24 feet in Panama bay, and between two and three feet on the Atlantic side of the Isthmus.

In speaking of the difficulties to be encountered in building a tide-water canal by the Panama route, I do not mean to say that they cannot be surmounted, but that they have been treated of in as light a manner as possible and a rose-colored appearance given to all estimates, in order to induce capitalists to engage in the undertaking is quite evident. M. De Lesseps appears to be going on with the undertaking, with what success remains to be seen.

In view of the opening of the St. Gothard Railway, it is proposed to connect the Adriatic with the Lago Maggiore by a system of canals, of which the termini will be at Venice and Magadino, in the Canton of Tessin. As the Po and the Cavour Canal can be utilized, the undertaking will be neither difficult nor costly, and a group of Italian bankers have promised their financial co-operation.

ON THE DYNAMO-ELECTRIC CURRENT, AND ON CERTAIN MEANS TO IMPROVE ITS STEADINESS.

By C. WILLIAM SIEMENS, D.C.L., F.R.S.

From Philosophical Transactions of the Royal Society.

On the 14th of February, 1867, I communicated a short paper to the Royal Society, describing the accumulative or dynamo-electrical principle of action, the conception of which I attributed to my brother Dr. Werner Siemens. When the paper was read, another paper followed by Sir Charles Wheatstone (sent in on the 24th February) also describing this principle of action, thus showing that the same line of thought had occupied that eminent philosopher.

In illustration of my paper I exhibited a machine of my design, embodying the accumulative principle of action, which furnished abundant evidence of the powerful nature of the current that could be thus produced. It consisted of two horseshoe electro magnets, between the poles of which a Siemens armature could be made to rotate, the machine being furnished with a handle or pulley for that purpose. A commutator was provided, by which the alternating currents set up in the rotating coil (after a first impulse had been given) were directed through the coils of the stationary electro magnets in a continuous manner, and proceeded thence outward to ignite a platinum wire of some 12″ in length, or to perform other work.

This machine, although the first of its kind, has done good service ever since its construction, having been found very efficacious in exciting powerful permanent magnets at the telegraph works of Siemens Brothers at Woolwich.

Since 1867 the accumulative principle has been employed in the machines of different makers, and one form of dynamo-electric machine, that of M. Gramme, differs very materially from the machine above referred to, and had met very deservedly with extensive recognition. M. Gramme embodied in his machine the principle of Professor Pacinotti's magnetic ring, which enabled him to produce powerful electric currents without much of the loss of energy caused in previous machines through the heating of the rotating armature.

Another modification of the dynamo-electrical machine is one devised by Mr. Von Heftner Alteneck, an engineer and physicist employed under my brother Werner Siemens, at Berlin. This machine differs from that first submitted by myself in several important particulars. Instead of the Werner Siemens armature, Von Heftner Alteneck adopted a rotating coil of iron wire wound with insulated copper wire in more than one direction, the several coils of wire being connected seriatim with the commutator, and through it, with the wire surrounding the soft iron bars, and with the electric lamp or other resistance on the outer circuit.

The advantage claimed for this mode of construction is that all the wire forming the rotating coil or helix is brought into the magnetic field, excepting only those portions crossing from side to side of the coil; and in order to reduce this unproductive resistance to a minimum, the rotating coil or helix has been made comparatively long, and the number of electro magnets has been increased generally to six or more.

The principal advantage of the dynamo-electrical machine over all other current generators consists in its power of producing currents of great magnitude, and of an intensity up to 100 volts, with a small primary resistance, and therefore with a comparatively small expenditure of mechanical energy. It labors, on the other hand, under the disadvantage that the power of the current depends, at a given velocity, upon the magnetic force developed in the electro magnets. This force depends upon the amount of current passing through the coils of the magnets, which in its turn is dependent in an inverse ratio upon the resistance in the outer circuit. If from some accidental cause the external resistance is increased, the electro-motive force of the machine, instead of rising to overcome the obstruction, diminishes, and thus aggravates the resulting disturbance. If, on the other hand, the resistance of the outer circuit diminishes, as in the case when the carbons of an electric regulator touch one another, the electro magnets are immediately excited to a maximum, and the electro-motive force of the machine is increased. The power absorbed and its equivalent, the heat generated in the circuit, is equal to the square of the electro-motive force divided by the resistance; hence the work demanded from the engine will be greatly increased, the machine may be dangerously overheated, and powerful sparks may injure the commutator. It is chiefly owing to this instability of the dynamo-electric current that its application to electric illumination has been retarded, and that magneto-electric machines and machines producing alternating currents have been again used, although they are inferior to the dynamo machine in the current energy produced for a given expenditure of mechanical energy.

The properties of dynamo-electric machines have been examined by several observers. Messrs. Houston and Thomson (Franklin Institute) compared the efficiency of the Gramme, Brush, and Wallace Farmer machines. Dr. Hopkinson (Institution of Mechanical Engineers, 25th April, 1879) examined a medium-sized Siemens machine, determined its efficiency, and expressed the electro-motive force as a function of the current. Herrn Mayer and Anerbach (*Wiedemanns, Annalen*, November, 1879) and M. Mascart have experimented on the Gramme machine, and Mr. Schwendler on both Gramme and Siemens machines.

The radical defect of the dynamo machine of ordinary construction, may be inferred from the results of these experiments. The remedy has, however, been in our hands from the time of the first announcement of the principle of these machines before the Royal Society, when Sir Charles Wheatstone pointed out that "a very remarkable increase of all the effects, accompanied by a diminution in the resistance of the machine, is observed when a cross wire is placed so as to divert a great portion of the current from the electro magnet."

Some of the constructors of dynamo machines, namely: Mr. Ladd in this country, and Mr. Brush in the United States of America, have taken advantage of this suggestion, the latter with the avowed object in view of obviating spontaneous changes of polarity in effecting electro precipitation of metals, and without perhaps having realized all of the advantages of which this mode of action is capable; others have refrained from doing so on account of difficulties resulting, as I shall endeavor to show, from an insufficient examination into some important physical conditions that require attention in order to realize economical results.

An ordinary medium-sized Siemens-Alteneck dynamo-electrical machine has wound on its rotating helix insulated copper wire of 2.5 m.m. diameter in 24 sections, representing a resistance of .4014 S. U.* The four electro-magnet coils connected seriatim are composed of copper wire of 5.5 m.m. diameter, presenting a total resistance of 0.3065 S. U.

If (as has frequently been done) the wires of this machine were to be connected as suggested in Sir Charles Wheatstone's original paper, thus making the outer circuit not continuous with but parallel to the coil circuit, and if the outer circuit had a resistance of one unit, it would follow that the total resistance to the current set up by the rotation of the armature would be reduced from

$$.4+.3+1.=1.7 \text{ to } .4+\frac{.3\times 1}{1+.3}=0.61 \text{ unit,}$$

causing a great increase of current, the major portion (in the proportion of 10 to 4) would flow through the electro magnets, thus causing a great increase of heating effect. The resistance of the field magnet must therefore be greatly increased, but if it were attempted to increase that resistance simply by reducing the diameter of the wire, and increasing the number of convolutions until the same thickness of coil was obtained, the magnetic excitement and with it the electro-motive force of the current produced at a given velocity of rotation

* The resistance coils used in these experiments were graduated according to the mercury system introduced by Dr. Werner Siemens, and adopted by the Telegraphic Convention at Vienna in 1868. The B. A. unit was determined in 1874 by Kohlrausch to be 1.0493 S. U., or combined with Lorenz's value of the S. U. afterwards adopted, 0.9797×10^9 C.G. S. units—as much as 2 per cent. below its ascribed theoretical value. Later determinations by H. F. Weber (Phil. Mag., March, 1878) makes the S. U. to be equal to 0.955×10^9 C. G. S. units, and thus the Ohm to be 0.2 per cent. higher than its ascribed value; if this latter value is used, the numerical results must be correspondingly altered.

would suffer a material decrease. The current flowing through the helix coil would moreover have to divide itself, and in order to reach the same limit in the outer circuit its intensity in the helix coil would have to be increased, causing it to heat more readily than before. It was necessary, therefore, to raise the effect of the magnet current to the same level as before with as small a proportion of the helix current as possible, in order to leave a maximum proportion of the current for the outer circuit. In order to effect this, the magnet bars had to be increased in length, and placed further apart so as to provide room for coils of greatly increased weight and dimensions; at the same time the helix wire had to be increased in diameter to give room for the aggregate current, but in reality I found it advantageous to increase the diameter of the same in a much greater proportion.

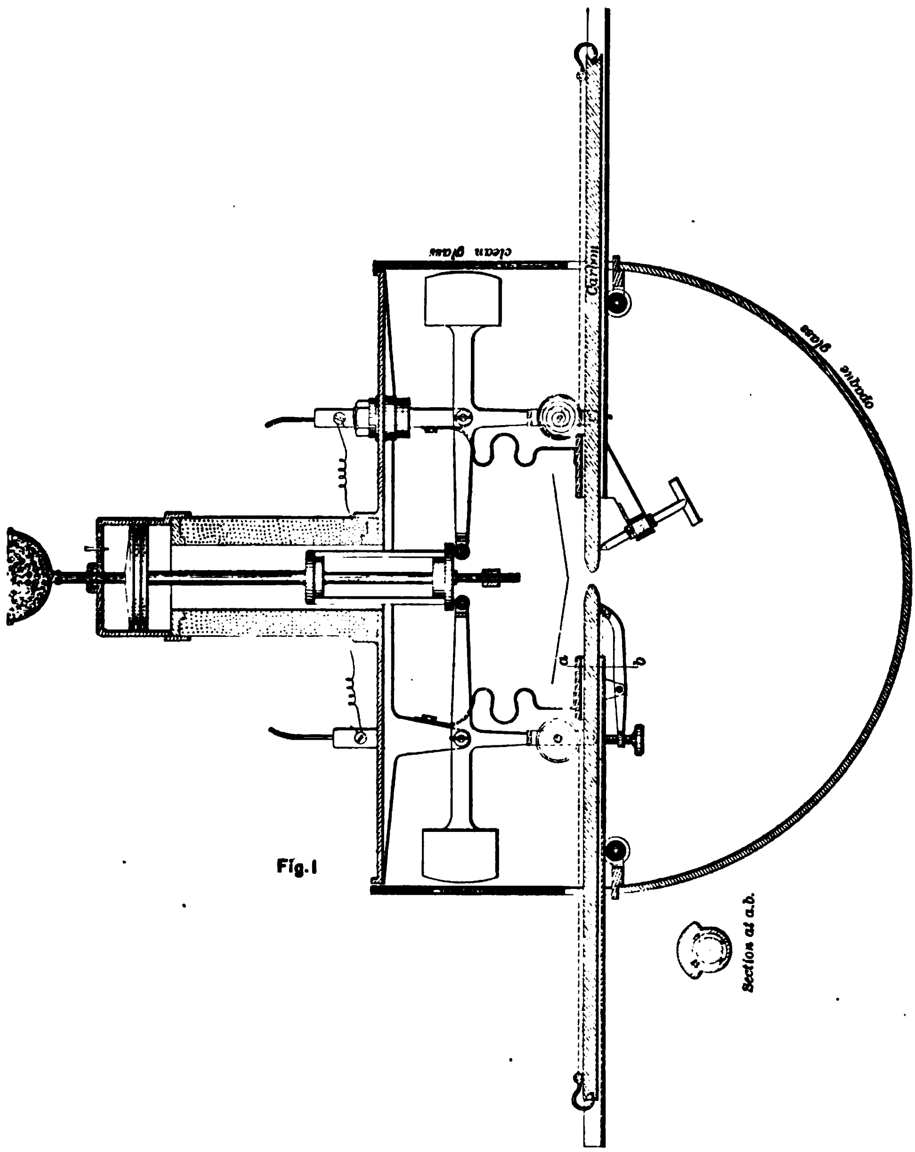


Fig. 1.

These general conditions having been determined by preliminary experiment, Mr. Lauckert, electrician engaged at my works, undertook a series of comparative experiments which are given in the appendix attached to this paper, and the results are given numerically and exhibited in curves. On examining the curves it will be remarked:

1. That the electro-motive force instead of diminishing with increased resistance, increases at first rapidly, then more slowly towards an asymptote.

2. That the current in the outer circuit is actually greater for a unit and a half resistance than for one unit.

3. With an external resistance of one unit, which is about equivalent to an electric arc when 30 or 40 webers are passing through it, 2.44 horse power is expended, of which 1.29 horse power is usefully employed; an efficiency of 53 per cent. as compared with 45 per cent. in the case of the ordinary dynamo machine.

4. That the maximum energy which can be demanded from the engine is 2.6 horse power, so that but a small margin of power is needed to suffice for the greatest possible requirement.

5. That the maximum energy which can be injuriously transferred into heat in the machine itself is 1.3 horse power, so that there is no fear here of destroying the insulation of the helix by excessive heating.

6. That the maximum current is approximately that which would be habitually used, and which the commutator and collecting brushes are quite capable of transmitting.

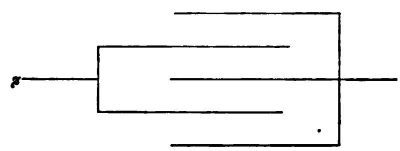
Hence I conclude that the new machine will give a steadier light than the old one, with greater average economy of power, that it will be less liable to derangement, and may be driven without variation of speed by a smaller engine; also that the new machine is free from the objection of having its currents reversed when used for the purpose of electro deposition.

The same peculiarity also enables me to effect an important simplification of the regulator to work electric lamps, to dispense with all wheel and clock-work in the arrangement, as shown in Fig. 1. The two carbons, being pushed onward by gravity or spring power, are checked laterally by a pointed metallic abutment, situated at such a distance from the arc itself that the heat is only just sufficient to cause the gradual wasting away of the carbon in contact with atmospheric air. The carbon holders are connected with the iron core of a solenoid coil, of a resistance equal to about fifty times that of the arc, the ends of which coil are connected with the two electrodes respectively. The weight of the core, which has to be maintained in suspension by the attractive force produced by the current, determines the distance between the electrodes, and hence the electric resistance of the arc. The result is that the length of the arc is regulated automatically so as to maintain a uniform resistance, signifying a uniform development of light.

APPENDIX.

The measurements of the electric currents were made with an electro dynamometer, the movable part of which consisted of a single turn of 4 m.m. wire, and the stationary coil of nine turns of the same.

To be able to reduce the electrical measurements into absolute power developed, it was in the first place necessary to determine the constant of the instrument in use. This was done in the following manner: Five copper plates of about 11″×8″ were connected as shown in the sketch.



These were carefully weighed and immersed in a solution of sulphate of copper. The machine was previously started, the time of immersion carefully noted, and the readings of the current taken every half minute. The plates were so arranged that the current entering at *a* and leaving at *z* deposited the copper on both sides of the plate at *z*. After a certain time the plates were taken out, quickly rinsed in water, and dried in sawdust. The plates were then carefully weighed again and the deposit calculated per degree reading on the instrument per second of time. Six independent measurements were taken with currents varying from 20 to 40 webers, and gave a mean of .000779 gramme of copper per second per degree reading. The differences of these measurements from the mean varied from 0.21 per cent. to 6.6 per cent., the mean of the differences being 1.98 per cent.

According to F. Kohlrausch (Pogg. Ann., Bd. cxlix., 1873) the quantity of silver deposited by the C. G. S. unit of electricity is 0.011363 gramme, and since the quantities vary as the equivalents of the metals deposited, we have

$$\frac{.011363\times 63.5}{216}=0.003340$$

gramme of copper.

One weber being $\frac{1}{10}$ C. G. S. unit, we have to divide by 10 the quantity of copper deposited by a current of one weber in one second, that is .000334 gramme, and dividing .000779 by .000334 we get 2.23323 webers for a degree reading of our instrument.

To be able to compare the machines having the new winding (*i. e.*, the wire on the electro magnets connected parallel with the outer circuit) with the ordinary machines, it was necessary to experiment on the relation existing between the power expended and the current produced with different resistances in circuit and different speeds.

A medium dynamo machine with 24 part commutator was used, the helix being wound with 336 convolutions of 2.5 m. m. wire, having a resistance of .4014 S. U. when measured in the machine. The electro magnets were wound with four layers of 5.5 m.m. wire, each having 32 convolutions, and therefore the four bobbins a total of 512 convolutions with a resistance of .3065 S. U.

The accompanying Tables Nos. 5, 6, 7, 8, and 9 give the details of the experiments made, which are shown graphically in the diagrams similarily numbered. The current in webers was simply calculated by multiplying the square root of the reading on the electro dynamometer with the constant of the instrument, *i. e.*, 2.3323.

To be able to calculate the electromotive force from the current in webers and resistance in Siemens' units, it was necessary to convert the S. U. into C.G.S. units by multiplying the same by $.9337\times 10^9$. (This figure is given by Lorenz, Pogg. Ann., Bd. cxlix., 1873.) By again multiplying this resistance into the current we get, according to Ohm's law, the electro-motive force in C. G. S. units, and by dividing by 10^8 we get the E. M. F. in volts.

I have further calculated the total amount of work developed in the following manner:

Work done $=E\times C\times t$, or, which is the same, $C^2\times R\times t$, where E is E. M. F; C, current; R, resistance; t, time.

From these calculations t is eliminated as it occurs in all the equations.

1 volt $=10^8$ C. G. S. units.
1 weber $=\frac{1}{10}$ C. G. S. unit of current.
1 HP $=7.46\times 10^9$ C. G. S. units.

Therefore

$$\frac{1\text{ volt}\times 1\text{ weber}}{1\text{ HP}}=\frac{10^8\times 10^{-1}}{7.46\times 10^9}=\frac{1}{746}$$

and if we multiply the E. M. F. in volts by the current in webers, and divide by 746, we have the actual work developed in horse power.

To find the actual work done in the outside resistance we use the formula $C^2\times R$, of course having to reduce the resistance R into absolute C. G. S. units by multiplying by $.9337\times 10^9$.

The machine with the new winding had a helix with 24 part commutator wound with 312 convolutions of 2.8 m.m. wire.

The electro-magnets being lengthened by 2″ to take bobbins 10½″, instead of 8½″ as on the ordinary machines, I had three sets of bobbins made, and had the same wound with different sizes of wire, viz.; 2.5 m.m., 2.8 m.m., and 3 m.m., having a respective resistance of 11.26, 7.563, and 4.46 S. U.

The accompanying Tables Nos. 1, 2, 3, and 4 show the experiments made with this machine with electro-magnets of 11.26 S. U. resistance; Nos. 10, 11, 12, and 13 with electro-magnets of 7.563 S.U.; and Nos. 14 and 15 with electro-magnets of 4.46 S. U. The helix in all cases having been wound with 2.8 m.m. wire with a resistance of .234 S. U. when measured in the machine.

The Tables marked 5, 6, 7, 8, and 9 refer to the dynamo machine wound in the ordinary way.

The Tables marked 16, 17, 18, 19, 20,

21, 22, and 23 show the results obtained with a machine having a helix wound with 288 convolutions of 3 m.m. wire and a resistance of .173 S. units. The electro-magnets, as before, had a resistance of 11.26, 7.563, and 4.47 S. U.

No. 1.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U. — In outer circuit.	Resistance in S. U. — Total in circuit.	Reading on electro-dynamometer. — Helix.	Reading on electro-dynamometer. — Electro-magnet.	Reading on electro-dynamometer. — Outer circuit.	Current in webers. — Helix.	Current in webers. — Electro-magnet.	Current in webers. — Outer circuit.	E. M. F. in helix in volts.	Horse power. — Expended.	Horse power. — Total Developed.	Horse power. — Developed in outer circuit.	Percentage of energy turned into useful work.
500	0.0	..	0.0	..	..	..	..	..	..	.205	..	..	..
"	.01	25	.5	..	..	1.63	..	..	.3804	"	.000831	..	..
"	.02	26	.5	..	..	1.63	..	..	.3957	"	.000864	..	..
"	.05	28	1.0	..	..	2.33	..	..	.6091	"	.00190	..	..
"	.10	34	1.5	..	..	2.86	..	..	.9079	"	.00348	..	..
"	.25	.48	2.0	..	..	3.30	..	..	1.479	"	.00654	..	..
"	.50	.72	14.0	1.0	12	8.80	2.33	8.08	5.915	.714	.0698	.0409	5.73
"	.75	.94	130.0	1.5	115	26.58	2.86	25.01	23.32	1.43	.881	.587	41.04
"	1.0	1.16	180.0	2.0	145	31.30	3.30	28.08	33.90	1.83	1.422	.987	53.93
"	1.25	1.36	145.0	2.0	125	28.08	3.30	26.07	35.65	"	1.342	1.063	58.08
"	1.5	1.56	135.0	3.0	115	27.09	4.04	25.01	39.46	"	1.433	1.17	63.93
"	1.75	1.75	132.0	3.0	102	26.79	4.04	23.55	43.77	"	1.592	1.21	66.12
"	2.0	1.94	120.0	3.5	95	25.55	4.36	22.73	46.28	1.73	1.585	1.29	69.94
"	∞	..	5.0	4.0	0	5.21	4.66	..	..	.714	..	..	..

No. 2.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U. — In outer circuit.	Resistance in S. U. — Total in circuit.	Reading on electro-dynamometer. — Helix.	Reading on electro-dynamometer. — Electro-magnet.	Reading on electro-dynamometer. — Outer circuit.	Current in webers. — Helix.	Current in webers. — Electro-magnet.	Current in webers. — Outer circuit.	E. M. F. in helix in volts.	Horse power. — Expended.	Horse power. — Total developed.	Horse power. — Developed in outer circuit.	Percentage of energy turned into useful work.
600	0.0	.24	0	..	..	..	..	..	..	.245	..	..	..
"	.25	.48	1	..	..	2.23	..	..	1.044	"	.0032	..	..
"	.50	.72	5	..	..	5.21	..	..	3.502	"	.0244	..	..
"	.75	.94	125	..	115	26.07	..	25.01	22.87	1.714	.799	.587	34.24
"	1.0	1.16	215	2.0	175	34.20	3.3	30.86	37.04	2.45	1.70	1.16	47.34
"	1.25	1.36	195	2.5	153	32.57	3.69	28.84	41.35	"	1.805	1.3	53.06
"	1.50	1.56	185	3.5	144	31.72	4.361	27.99	46.20	2.33	1.96	1.47	63.09
"	1.75	1.75	164	4.0	125	29.87	4.66	26 07	48.80	2.20	1.95	1.49	67.72
"	2.0	1.94	160	4.0	120	29.50	4.66	25.55	53.43	"	2.12	1.633	74.23
"	∞	11.50	6	5.0	0	5.71	5.21	..	65.66	1.10	.503	..	..

No. 3.

Helix: 24 part commutator, 312 convolutions, 2.3 m.m. wire, .234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
700	0.0	.24	..	..	..	..	..	..	..	.29	..	..	..
"	.25	.48	4	..	..	4.66	..	..	2.078	"	.0129	..	..
"	.5	.72	11	..	..	7.74	..	..	5.208	"	.0540	..	..
"	.75	.94	285	5	255	39.87	5.21	37.25	34.56	2.57	1.83	1.3	55.58
"	1.0	1.18	325	6	280	42.05	5.71	39.08	46.38	3.47	2.61	1.9	54.75
"	1.25	1.36	300	6	250	40.40	5.71	36.88	51.3	"	2.77	2.13	61.37
"	1.5	1.56	276	6	205	38.75	5.71	33.39	55.81	"	2.90	2.09	60.23
"	1.75	1.75	230	6	170	35.37	5.71	30.41	57.79	"	2.74	2.08	58.50
"	2 0	1.94	215	7	158	34.2	6.17	29.81	61.95	3.28	2.84	2.15	65.54
"	∞	11.50	11	10	0	7.74	7.37	..	33.11	1.29	.862	..	..

No. 4.

Helix: 24 part commutator, 312 convolutions, 2.3 m.m. wire, .234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned in to useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
758	12.30	6.11	38	9.0	9	14.38	6.99	6.99	82.08	2.78	1.58	:752	27.26
756	8.90	5.21	49	8.5	14	16.32	6.77	8.88	79.38	2.93	1.74	.872	29.96
734	6.00	4.15	69	9.0	28	19.37	6.99	12.34	75.05	3.0	1.95	1.14	38.00
758	6.00	4.15	72	9.0	28	19.79	6.99	12.34	76.67	3.09	2.08	1.14	36.89
750	4.50	3.43	85	9.0	34	21.50	6.99	13.61	68.85	3.21	1.98	1.04	32.40
756	3.50	2.91	150	7.0	87	28.56	6.17	21.75	77.59	3.86	2.97	2.17	52.07
760	3.00	2.61	185	6.0	107	31.72	5.71	24.12	77.30	3.88	3.29	2.18	56.18
758	2.50	2.28	204	5.0	130	33.31	5.21	26.58	70.91	3.87	3.17	2.21	57.11
750	2.25	2.12	230	..	150	35.37	..	28.56	70.01	3.83	3.32	2.30	60.01
760	2.00	1.94	226	..	157	35.06	..	29.27	68.51	3.88	2.99	2.14	55.15
755	1.75	1.75	252	..	180	37.08	..	31.30	60.50	3.85	3.00	2.14	55.58
754	1.50	1.56	255	..	185	37.25	..	31.72	54.26	3.85	2.71	1.89	49.10
760	1.35	1.44	305	..	240	41.20	..	36.14	54.71	3.72	2.99	2.21	59.41
756	1.25	1.36	310	..	245	41.06	..	36.50	52.14	3.70	2.89	2.08	56.48
764	1.10	1.24	315	..	260	41.20	..	37.61	47.70	3.74	2.63	1.94	51.87
766	1.00	1 16	315	..	264	40.78	..	37.89	44.62	3.59	2.46	1.80	50.01
750	.90	1.07	285	..	238	39.37	..	35.98	39.33	3.06	2.07	1.46	47.71
765	.80	.99	285	..	205	35.75	..	33.39	33.04	2.50	1.58	1.12	44.80
760	.75	.94	208	..	185	33.64	..	31.30	29.52	2.48	1.33	.92	37.09
755	.65	.85	98	..	87	23.09	..	21.75	18.32	1.08	.567	.385	35.64
760	.60	.81	50	..	45	16.49	..	15.64	12.47	1.08	.275	.184	17.08
700	.55	.76	30	..	25	12.77	..	11.68	9.07	.43	.155	.094	21.86
752	.50	.72	12	..	10	8.07	..	7.37	6.36	.46	.069	.034	7.39
..	.40	.65	5	..	4	5.21	..	4.66	3.16	..	.0231	.0109	2.37
..	∞	11.50	12	12.00	..	8.07	8.07	..	36.64	..	.937	..	..

No. 5.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.5 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
750	∞	..	..	..	..	.306	..	..	..
"	8.9	9.61	1	2.33	20.90	"	.0653	.0605	19.77
"	6.0	6.71	1	"	14.59	"	.0455	.0408	13.33
"	4.5	5.21	1	"	11.33	"	.0353	.0306	10.00
745	3.5	4.21	7	6.17	24.25	.304	.205	.167	54.93
760	3.25	3.96	16	9.32	34.46	.620	.430	.353	56.90
758	3.0	3 71	26	11.89	41.18	.773	.656	.531	68.70
750	2.75	3.46	40	14.75	47.65	1.224	.942	.749	61.19
740	2.5	3.20	66	18.95	56.62	1.660	1.44	1.12	67.67
756	2.25	2 96	85	21.50	59.42	2.16	1.71	1.30	60.1?
774	2.0	2.71	120	25.55	64.65	2.69	2.21	1.63	60.59
768	1.75	2.46	165	29.96	68.81	3.45	2.76	1.97	57.10
736	1.5	2.21	215	34.20	70.57	3.90	3.23	2.20	56.41
710	1.25	1.96	260	37.61	68.80	4.35	3.47	2.21	50.80
724	1.0	1.71	330	42 37	67.65	5.02	3.84	2.25	44.82
736	.9	1.61	520	53.17	79.92	6.16	5.69	3.16	51.29
"	.8	1.51	570	55.67	78.49	6.91	5.86	3.10	44.87
"	.75	1.46	625	58.31	79.48	6.91	6.21	3.19	46.16

No. 6.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.5 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
500	3.5	..	..	..	..	.257	..	..	..
496	3.0	3.71	1.5	2.86	9.90	.405	.0379	.0307	7.58
505	2.5	3.21	2	3.29	9.86	.515	.1434	.0338	6.563
516	2.0	2.71	9	6.99	17.68	.579	.165	.122	21.07
520	1.75	2.46	42	15.11	34.70	.796	.702	.500	62.81
490	1.5	2.21	60	18.06	37.26	1.20	.902	.612	51.00
496	1.25	1.96	120	25.55	46.75	1.82	1.61	1.02	56.04
490	1.0	1.71	180	31.30	49.97	2.30	2.09	1.23	53.47
490	.85	1.56	245	36.50	53.16	2.80	2.60	1.42	50.71
504	.75	1.46	280	39.03	53.20	3.08	2.78	1.43	46.42
502	.65	1.36	320	41.72	52.97	3.08	2 96	1.41	45.79
"	.60	1.31	340	43.01	52.60	3.58	3.03	1.39	38.83
"	.55	1.26	355	43.94	51.68	3.58	3.04	1.33	37.15
488	.50	1.21	385	45.76	51.70	3.58	3.17	1.25	34.92
"	.45	1.16	420	47.80	51.77	3.78	3.32	1.29	34.13
"	.40	1.11	491	51.63	53.49	3.98	3.70	1.33	33.42
"	.35	1.06	510	52.66	52.10	4.08	3.68	1.21	29.65
"	.30	1.01	600	57.12	53.89	4.28	4.12	1.22	28.51
"	.25	.96	630	58.54	52.46	4.58	4.11	1.07	23.36

No. 7.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.5 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
602	4.5	5.21	..	..	..	.246	..	..	..
"	3.5	4.21	..	..	..	.491	..	..	..
590	3.0	3.71	1	2.33	8.07	.603	.0252	.0203	3.372
602	2.5	3.21	16	9.32	27.93	.676	.349	.2725	40.31
606	2.0	2.71	60	18.06	45.69	1.118	1.106	.816	73.31
602	1.75	2.46	105	23.90	54.89	1.72	1.760	1.25	72.67
600	1.5	2.21	140	27.59	56.93	2.20	2.110	1.429	64.95
590	1.25	1.96	170	30.41	55.65	2.53	2.27	1.45	57.31
600	1.0	1.71	270	33.32	61.18	3.43	3.14	1.84	53.64
620	.85	1.56	378	45.34	66.04	4.43	4.01	2.18	49.21
"	.75	1.46	400	46.64	68.57	4.68	3.97	2.05	43.80
"	.60	1.31	505	52.41	64.11	5.06	4.50.	2.06	40.71

No. 8.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.5 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
715	4.5	5.21	..	..	.	.365	..	..	..
696	3.5	4.21	4	4.66	18.32	.427	.114	.095	22.25
700	3.0	3.71	21	10.69	37.03	1.43	.530	.429	30.00
710	2.5	3.21	50	16.49	49.42	1.59	1.09	.682	42.89
680	2.0	2.71	105	23.91	60.50	2.64	1.94	1.43	54.16
690	1.75	2.46	165	29.96	63.11	3.94	2.76	1.98	50.25
708	1.5	2.21	210	33.80	69.75	3.90	3.16	2.14	54.87
685	1.25	1.96	270	38.32	70.13	4.47	3.60	2.30	51.45
686	1.0	1.71	380	45.46	72.58	5.04	4.42	2.59	51.29
720	.85	1.56	550	54.69	79.66	6.46	5.14	3.18	49.22
"	.75	1.46	620	58.07	79.16	6.76	6.16	3.16	46.74
"	.60	1.31	680	60.83	74.41	7.05	6.07	2.78	39.43
"	.50	1.21	900	69.97	79.05	7.72	7.42	3.06	39.63

No. 9.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.6 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total Developed.	Developed in outer circuit.	
450	1	1.71	100	23.33	37.24	1.56	1.16	.681	43.65
500	"	"	145	28.08	44.84	2.14	1.69	.987	46.12
550	"	"	190	32.14	51.32	2.69	2.21	1.29	47.95
600	"	"	235	35.75	57.08	3.43	2.73	1.60	46.65
650	"	"	290	39.72	63.42	4.24	3.37	1.97	46.46
700	"	"	360	44.25	70.65	5.00	4.18	2.45	49.00
750	"	"	420	47.80	76.32	5.81	4.89	2.86	49.22
800	"	"	490	51.63	82.44	6.86	5.70	3.34	48.69

No. 10.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.568 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
502	∞	7.8	13	13	..	8.41	8.41	..	61.25	1.83	.69	..	..
513	12.0	4.87	30	12	5	12.77	8.08	5.21	58.07	1.47	.994	.409	27.82
517	10.0	4.54	35	12	7	13.80	8.08	6.17	58.50	1.58	1.062	.476	30.12
520	9.0	4.34	42	12	9	15.11	8.08	7.0	61.23	1.59	1.251	.552	34.72
496	7.5	3.99	40	10	10	14.75	7.87	7.87	54.95	1.42	1.086	.510	35.90
501	6.0	3.51	42	8	15	15.11	6.60	9.03	50.86	1.53	1.020	.612	40.00
500	4.5	3.05	50	7	22	16.49	6.17	10.94	46.96	1.53	1.038	.674	44.05
510	3.5	2.62	75	7	35	20.20	6.17	13.8	49.41	1.77	1.338	.834	47.12
502	3.0	2.38	82	6	42	21.12	5.71	15.11	46.98	1.74	1.329	.857	49.25
507	2.5	2.11	90	6	50	22.12	5.71	16.49	43.58	1.86	1.292	.851	45.75
502	2.0	1.81	120	6	85	25.55	5.71	21.5	43.18	1.95	1.479	1.11	56.92
495	1.75	1.65	140	6	95	27.59	5.71	22.73	42.5	1.92	1.572	1.13	58.85
493	1.5	1.48	160	5	110	29.50	5.21	24.46	40.77	2.01	1.612	1.12	55.72
504	1.25	1.30	190	4	140	32.14	4.66	27.59	39.01	2.16	1.681	1.19	55.09
506	1.1	1.19	205	4	157	33.89	4.66	29.21	37.12	2.27	1.661	1.16	51.10
512	1.0	1.11	200	4	155	32.98	4.66	29.08	34.18	2.09	1.511	1.05	50.23
505	.85	.998	225	4	180	34.98	4.66	31.30	32.60	1.96	1.528	1.04	53.06
510	.75	.917	220	4	183	34.60	4.66	31.55	29.63	1.87	1.374	.934	49.95
507	.6	.790	160	3	120	29.50	4.04	25.55	21.77	1.45	.861	.490	33.79

No. 11.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.568 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
598	.3	.52	3	1	3	4.04	2.33	4.04	1.962	.24	.0106	.00613	2.554
596	.4	.61	4	1	3	4.66	2.33	4.04	2.655	.24	.0166	.00817	3.404
612	.5	.70	30	1	26	12.77	2.33	11.89	8.34	.375	.143	.0884	23.57
"	.6	.79	180	2	..	31.30	3.30	..	23.08	.87	.968	..	..
620	.6	.79	215	2	180	34.20	3.30	31.30	25.23	1.77	1.16	.736	41.58
615	.7	.87	230	3	240	39.03	4.04	36.14	31.71	2.26	1.66	1.14	50.44
"	.75	.917	300	4	250	40.40	4.66	36.88	34.59	2.51	1.87	1.28	51.50
600	.85	.998	290	4	245	39.72	4.66	36.50	37.02	2.571	1.97	1.42	55.25
612	1.0	1.11	305	6	235	40.73	5.71	35.75	42.21	2.87	2.30	1.60	55.74
"	1.25	1.30	290	7	210	39.72	6.17	33.80	48.22	2.86	2.56	1.80	62.93
598	1.5	1.48	230	8	160	35.37	6.60	29.50	48.88	2.81	2.32	1.63	58.00
615	2.0	1.81	195	10	120	32.57	7.34	25.55	55.05	2.89	2.40	1.68	56.40
620	3.0	2.38	130	12	65	26.58	8.08	18.80	59.07	2.66	2.10	1.33	50.00
625	4.5	3.05	85	14	32	21.50	8.83	13.19	61.23	2.30	1.76	.98	42.61
"	6.0	3.59	70	15	22	19.51	9.03	10.94	65.40	2.16	1.71	.896	41.57
620	7.5	3.99	55	16	16	17.29	9.33	9.33	64.42	1.89	1.49	.817	42.23

No. 12.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
700	7.5	4.01	80	18	18	20.86	9.89	9.89	78.10	2.57	2.18	.918	35.72
"	6.0	3.59	80	17	25	20.86	9.62	11.68	69.92	2.57	1.95	1.02	39.69
707	4.5	3.06	95	16	35	22.73	9.33	13.80	64.94	2.88	1.97	1.07	37.15
710	3.0	2.39	165	14	90	29.96	8.88	22.12	66.85	3.19	2.68	1.84	57.67
704	2.5	2.12	195	12	115	32.57	8.08	25.01	64.47	3.59	2.81	1.96	54.59
716	2.0	1.82	235	9	150	35.75	7.0	28.56	60.75	3.94	2.91	2.04	51.77
723	1.5	1.49	315	7	220	41.40	6.17	34.60	57.60	4.28	3.20	2.25	52.57
715	1.25	1.31	350	6	260	43.64	5.71	37.61	53.38	4.23	3.12	2.21	52.25
722	1.0	1.12	385	5	300	45.76	5.21	40.40	47.85	4.27	2.98	2.04	47.77
705	.75	.92	370	5	305	44.86	5.21	40.78	38.58	3.45	2.81	1.56	45.21
708	.60	.80	300	5	270	40.40	5.21	38.32	30.18	2.90	1.63	1.10	48.08
716	.50	.71	150	4	100	28.56	4.66	23.32	18.94	.292	.725	.84	11.64
710	.40	.62	7	1	7	6.17	2.33	6.17	3.571	.290	.295	.019	6.552

No. 13.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
450	1.0	1.12	140	..	105	27.59	..	23.91	28.85	1.47	1.02	.715	48.63
500	"	"	185	..	150	31.72	..	28.56	33.16	1.94	1.41	1.02	52.57
550	"	"	250	..	195	36.88	..	32.57	38.56	2.47	1.91	1.33	53.85
600	"	"	325	..	260	42.05	..	37.61	43.97	3.06	2.48	1.77	57.84
650	"	"	400	..	305	46.64	..	40.78	48.77	3.71	3.05	2.08	56.06
700	"	"	470	..	350	50.56	..	43.64	52.87	4.43	3.58	2.38	53.72
750	"	"	530	..	395	53.69	..	46.35	56.14	5.20	3.91	2.69	51.73
800	"	"	640	..	460	58.98	..	50.03	61.69	5.88	4.86	3.13	53.23
850	"	"	700	..	510	61.69	..	52.66	64.51	6.42	5.33	3.47	54.05
900	"	"	785	..	570	65.33	..	55.67	68.31	6.98	5.98	3.88	55.59
850	"	"	700	..	505	61.69	..	52.41	64.51	6.42	5.33	3.44	53.58
800	"	"	600	..	440	57.12	..	48.92	59.73	5.71	4.57	2.99	52.36
750	"	"	510	..	372	52.66	..	44.98	55.07	4.90	3.89	2.53	51.63
700	"	"	440	..	330	48.92	..	42.37	51.15	4.14	3.35	2.25	54.35
650	"	"	350	..	270	43.64	..	38.32	45.63	3.45	2.67	1.84	53.33
600	"	"	285	..	220	39.47	..	34.60	41.27	2.82	2.18	1.5	53.19
550	"	"	240	..	180	36.14	..	31.30	37.79	2.24	1.83	1.23	54.91
500	"	"	180	..	135	31.30	..	27.09	32.73	1.73	1.37	.918	53.06
450	"	"	135	..	100	27.09	..	23.32	28.33	1.28	1.03	.681	53.20

No. 14.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 2240 convolutions, 3 m.m. wire, 4.46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
505	∞	4.70	23	23	.	11.19	11.19	..	49.01	1.34	.736	..	..
510	7.0	2.96	55	..	9	17.29	..	6.99	47.79	1.77	1.11	.428	24.18
502	6.0	2.8	60	..	12	18.06	..	8.08	47.21	1.74	1.14	.490	28.16
502	5.0	2.6	65	18	14	18.80	9.89	8.88	45.64	1.74	1.15	.493	28.33
492	4.5	2.48	65	16	16	18.80	9.33	9.32	43.53	1.71	1.10	.489	28.60
"	3.0	2.08	120	15	40	25.55	9.08	14.75	48.48	1.71	1.66	.817	47.78
515	2.5	1.84	125	14	53	26.07	8.88	16.98	44.79	1.99	1.57	.902	45.32
494	2.0	1.62	145	18	7	28.08	8.40	19.51	42.47	1.91	1.60	.953	49.39
"	1.5	1.36	180	10	100	31.20	7.37	23.82	39.75	2.01	1.67	1.02	50.74
508	1.25	1.22	210	..	130	33.80	..	26.58	38.50	2.18	1.74	1.10	50.46
512	1.0	1.06	260	9	170	37.61	6.90	30.41	32.73	2.40	1.65	1.16	48.33
515	1.0	1.06	280	..	180	39.08	..	31.30	38.65	2.41	2.02	1.23	51.08
506	.9	.99	295	..	205	40.06	..	33.39	36.93	2.37	1.98	1.25	52.74
515	.8	.92	220	7	220	34.60	6.17	34.60	29.72	2.52	1.38	1.20	47.61
"	.7	.84	295	..	222	40.06	..	34.75	31.42	2.52	1.69	1.05	41.67
498	.3	.52	95	2	75	22.73	3.29	20.20	11.04	0.71	.336	.153	21.55
510	.6	.77	260	5	200	39.03	5.21	32.98	28.06	2.18	1.47	.817	37.48
"	.5	.69	275	..	210	38.68	..	33.80	24.92	2.42	1.29	.715	29.54

No. 15.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 2240 convolutions, 3 m.m. wire, 4.46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
700	..	.24	..	..	..	..	..	..	..	.28	..	..	..
"	.1	.34	2	..	..	8.29	..	..	1.044	.28	.0046	..	..
"	.2	.43	3	..	..	4.03	..	..	1.617	.28	.0067	..	..
712	.3	.52	14	..	10	8.88	..	7.37	4.311	.29	.0518	.0204	7.084
698	.4	.61	15	..	12	9.03	..	8.07	5.148	.28	.0622	.0326	11.64
712	.5	.69	370	4	305	44.86	4.66	40.78	28.89	2.61	1.74	1.04	39.84
715	.6	.77	510	6	370	52.66	5.71	44.86	37.86	3.50	2.67	1.51	43.14
"	.75	.88	570	..	360	55.67	..	44.25	45.74	4.08	3.41	1.83	44.85
720	1.0	1.06	630	15	335	53.69	9.03	42.69	53.14	4.10	3.82	2.28	55.61
714	1.25	1.22	440	18	260	48.93	9.80	37.61	55.73	4.08	3.66	2.21	54.16
708	1.5	1.36	410	21	215	47.23	10.69	34.20	59.97	4.05	3.80	2.20	54.32
700	2.0	1.62	325	25	150	42.05	11.68	28.56	68.60	4.00	3.58	2.04	51.00
712	3.0	2.03	230	32	80	35.37	13.19	20.86	67.04	3.48	3.18	1.63	46.83
"	∞	4.7	..	50	..	..	16.65	..	..	2.47	..	..	..

No. 16.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
612	0.0	..	..	..	..	..	..	..	..	.25	..	..	..
640	.25	.418	..	..	..	..	..	..	..	.25	..	..	..
625	.5	.652	4	..	..	4.66	..	..	2.84	.25	.018	..	..
620	.75	.876	97	..	90.0	22.97	..	22.12	18.8	.76	.579	.46	60.6
630	1.0	1.09	220	2.0	190.0	34.6	3.3	32.14	35.21	2.44	1.63	1.29	52.86
630	1.25	1.29	225	3.0	190.0	34.98	4.04	32.14	41.18	2.57	1.93	1.61	62.64
635	1.5	1.5	205	3.5	170.0	33.39	4.36	30.41	46.76	2.59	2.09	1.78	66.79
636	1.75	1.69	185	3.5	145.0	31.72	4.36	28.08	50.05	2.46	2.13	1.73	70.32
638	2.0	1.87	165	4.0	120.0	29.96	4.66	25.55	52.3	2.47	2.10	1.63	75.99
628	4.5	3.38	68	6.0	32.0	19.23	5.71	13.19	60.69	2.05	1.56	.93	47.36
624	6.5	4.29	42	7.0	15.0	15.11	6.16	9.03	60.52	1.91	1.22	.66	34.55
635	9.0	5.17	32	7.5	8.5	13.19	6.39	6.8	63.67	1.81	1.13	.521	28.78
610	11.0	5.73	25	7.0	7.0	11.68	6.16	6.16	62.49	1.62	.93	.522	32.22
614	∞	11.43	8	8.0	..	6.6	6.6	..	70.43	1.25	.623	..	..

No. 17.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
665	.25	.42	3	..	3	4.04	..	4.04	1.58	.271	.0065	.0051	1.82
670	.5	.652	30	..	28	12.77	..	12.34	7.74	.547	.132	.095	17.37
665	.75	.875	245	2.0	225	36.50	3.3	34.98	29.85	2.04	1.45	1.14	55.88
660	.85	.963	255	2.5	235	37.25	3.69	35.75	33.49	2.29	1.67	1.36	59.38
640	1.0	1.09	290	3.0	260	39.72	4.04	37.61	40.42	2.61	2.15	1.77	67.81
645	1.1	1.17	272	3.0	230	38.47	4.04	35.37	42.02	2.63	2.17	1.72	65.40
650	1.25	1.29	250	3.5	205	36.88	4.36	33.39	44.42	2.65	2.2	1.74	65.66
645	1.4	1.42	235	4.0	185	35.75	4.66	31.72	47.89	2.63	2.27	1.76	66.92
650	1.5	1.5	226	4.0	180	35.22	4.66	31.3	49.38	2.52	2.33	1.84	73.01
660	1.75	1.69	300	4.5	158	32.98	4.94	28.84	52.04	2.56	2.3	1.82	71.09
660	2.0	1.87	180	5.0	145	31.3	5.21	28.06	54.65	2.42	2.29	1.97	81.40

No. 18.

Helix : 25 parts commutator, 278 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets : 3,916 convolutions, 2.5 m.m. wire, 11.26 S. U, resistance.

Revolutions per minute.	Resistance in S.U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
817	1.1	1.17	485	..	360	48.65	..	44.25	53.15	4.67	3.47	2.69	57.6
812	1.0	1.09	465	..	385	50.29	..	45.76	51.11	4.81	3.44	2.61	54.26
815	1.25	1.29	405	5.0	335	46.94	5.21	42.69	56.58	4.82	3.56	2.85	59.12
830	1.5	1.5	370	5.5	290	44.86	5.47	39.72	62.83	4.85	3.78	2.96	61.03
814	1.75	1.69	330	..	250	42.87	..	36.88	66.85	4.82	3.8	2.98	61.82
812	2.0	1.87	300	..	220	40.40	..	34.6	70.54	4.64	3.32	3.00	64.65
824	.9	1.01	450	..	385	49.47	..	45.76	46.65	4.71	3.09	2.36	50.10
820	.8	.92	450	..	390	49.47	..	46.06	42.56	4.35	2.82	2.12	48.73
808	.75	.876	430	..	390	48.36	..	46.06	39.55	4.12	2.56	1.99	48.30
840	.6	.748	220	..	215	34.60	..	34.2	24.00	2.4	1.11	.878	36.58
830	.5	.652	..	..	100	..	..	23.32	..	2.37	..	.34	14.34
820	.5	.652	75	..	70	20.20	..	19.51	12.30	2.34	.333	.238	10.16

No. 19.

Helix : 24 part commutator, 288 convolutioos, 3 m. m. wire, .173 S. U. resistance.
Electro-magnets : 3916 convolutions, 2.5 m. m. wire, 11.26 S. U. resistance,

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
480	1.0	1.091	98		85	23.09	..	21.5	23.53	1.37	.728	.578	42.19
530	"	"	185		123	27.09	..	25.86	27.60	1.73	1.00	.837	48.38
602	"	"	223	..	195	34.83	..	32.57	35.49	2.33	1.66	1.33	57.08
670	"	"	290	..	250	39.72	..	36.88	40.47	3.14	2.15	1.7	54.14
744	"	"	390	..	320	46.06	..	41.72	46.93	3.95	2.89	2.18	55.19
800	"	"	455	..	380	49.75	..	45.46	50.70	4.73	3.38	2.59	54.76
864	"	"	515	..	430	52.92	..	48.36	53.92	5.64	3.82	2.93	51.95
911	"	"	585	..	490	56.42	..	51.63	57.49	6.32	4.35	3.34	52.85

No. 20.

Helix : 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets : 3,200 convolutions, 2.8 m m. wire, 7,568 U. S. resistance.

Revolutions per minute.	Resistance in U.S.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	Outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
716	∞	7.74	26	26.0	..	11.89	11.89	..	85.98	2.04	1.37	..	..
710	2.0	1.75	300	15.0	195	40.4	9.03	32.57	66.01	3.62	3.57	2.66	73.48
706	1.75	1.59	320	13.5	220	41.72	8.57	34.6	61.93	3.74	3.46	2.62	70.05
718	1.5	1.42	360	12.0	255	44.25	8.08	37.25	58.66	3.96	3.48	2.61	65.91
710	1.25	1.25	395	9.0	290	46.35	6.99	39.72	54.10	4.06	3.36	2.47	60.84
708	1.0	1.06	445	7.0	340	49.21	6.16	43.01	48.70	4.04	3.21	2.31	57.18
714	.95	1.02	460	6.0	360	50.08	5.71	44.25	47.65	3.79	3.2	2.33	61.47
706	.9	.977	460	..	370	50.08	..	44.86	45.64	3.75	3.19	2.27	60.53
710	.8	.896	460	5.0	380	50.23	5.21	45.46	41.85	3.62	2.81	2.07	57.18
714	.7	.814	445	4.0	375	49.20	4.66	45.16	37.40	3.35	2.47	1.78	53.13
715	.6	.729	390	..	340	46.06	..	43.01	31.35	2.77	1.94	1.39	50.18
715	.5	.642	..	..	230	..	..	35.37	..	..	..	.875	..
710	.5	.642	205	..	195	33.39	..	32.57	20.02	1.3	.896	.665	51.15

No. 21.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current on webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	Outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
468	1.0	1.06	170	..	130	30.41	..	26.58	30.10	1.34	1.23	.884	65.97
532	"	"	235	..	185	35.75	..	31.72	35.38	1.96	1.69	1.26	64.21
610	"	"	310	..	240	41.06	..	36.14	40.64	2.61	2.24	1.64	62.83
678	"	"	365	..	290	44.56	..	39.72	44.10	3.32	2.63	1.98	59.64
716	"	"	430	..	335	48.36	..	42.68	47.86	3.79	3.10	2.28	60.16
788	"	"	510	..	385	52.66	..	45.76	52.12	4.35	3.67	2.63	60.46
860	"	"	620	..	430	57.14	..	48.36	56.55	5.08	4.33	2.93	57.68

No. 22.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets: 2556 convolutions, 3 m.m. wire, 4.46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
690	∞	4.63	46	46	..	15.82	15.82	..	68.4	2.67	1.45	..	..
702	2.0	1.55	300	24	155	40.4	11.43	29.08	58.47	4.01	3.16	2.11	52.62
694	1.75	1.48	300	22	170	40.4	10.94	30.41	53.94	3.97	2.92	2.08	51.18
698	1.5	1.29	335	20	205	42.69	10.43	33.39	51.42	3.99	2.94	2.09	52.38
696	1.25	1.15	390	18	245	46.06	9.9	36.50	49.46	4.12	3.06	2.08	50.48
696	1.0	.99	395	14	265	46.35	8.88	37.97	42.85	3.98	2.67	1.8	45.22
690	.9	.92	390	9	290	46.06	6.99	39.72	39.56	3.52	2.44	1.78	50.57
649	.8	.85	385	8	290	45.75	6.6	39.72	36.32	3.39	2.22	1.58	46.61
706	.7	.78	360	7	270	44.25	6.16	38.32	32.14	3.02	1.9	1.29	42.71
684	.6	.702	290	..	245	39.72	..	36.50	26.02	2.65	1.38	1.0	37.73
684	.5	.623	..	..	160	..	..	29.50	..	1.26	..	.544	43.18
684	.5	.623	140	..	..	27.59	..	..	16.05	1.26	.594	..	..

No. 23.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets, 2556 convolutions, 3 m.m. wire, 4.46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	Outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
492	1	.99	240	7.0	160	36.14	6.16	29.5	33.41	2.11	1.62	1.09	51.66
528	"	"	282	9.0	185	39.17	6.99	31.72	36.21	2.48	1.9	1.26	50.81
602	"	"	345	12.0	235	43.31	8.08	35.75	40.04	3.07	2.32	1.6	52.12
684	"	"	410	14.0	280	47.23	8.88	39.08	43.66	3.61	2.76	1.9	52.63
722	"	"	450	16.0	300	49.47	9.33	40.4	45.73	4.27	3.08	2.04	47.78
790	"	"	540	18.5	335	54.20	10.08	42.69	50.10	5.0	3.64	2.28	45.60
856	"	"	610	21.0	370	57.60	10.69	44.86	53.24	5.76	4.11	2.52	43.74

ON THE PROBABLE DURATION OF IRON STRUCTURES.

By DR. H. FRIITZSCHE.

From Mittheilungen des Sächsischen Ingenieur-und Architekten-Vereins, for Abstracts of papers of the Institution of Civil Engineers.

Attention was first drawn to this subject at a sectional meeting of the German Engineering Union in 1873, and reports were invited from the Saxon and Hanoverian Societies. On behalf of the latter, Herr Launhardt expressed the opinion that the failure of iron structures is caused, not so much by molecular changes and loosening of rivets, as by rust, and that scarcely perceptible deformation would take place beforehand.

The Hamburg Society mooted the idea that the question of duration was one with that of resisting power, and that uniformly repeated observations might therefore be replaced by periodic load tests.

The Berlin Architects' Society recommended the division of observations into special and general; the latter to embrace: 1. Measurement of permanent deflection; Measurement of deflection under a load; 3. Enumeration of constructional pieces and rivets already repaired; 4. Examination of any existing looseness of the connections at points of junction; 5. Examination of the paint and any existing rusted places. The special observations were to supplement the general and to embrace measurement of; 6. the deflection of the lower boon under a moving load; 7. the distance between upper and lower booms; 8. the lengths of diagonals; 9. horizontal swinging in the middle of the girder. It was added, that (*a*) for each structure a special observation book must be drawn up; (*b*) the general observations should be repeated quinquennially, the special once a year; (*c*) all observations, where possible, should be made by the same observer; (*d*) repairs to important parts of the structure, and the soundness of the material as well as of the connections, should be carefully examined.

From the various suggestions received the author has drawn up a scheme of notes to be made.

For bridge girders, two tables, one for permanent, the other for elastic bending, are given with vacant spaces for the insertion of—date of observation; temperature and state of the weather; the position of the marks

$$a,\ b,\ c,\ \left(\overset{d}{\underset{a\qquad b\qquad c}{\left|<\frac{E}{2}\times\frac{E}{2}>\right|}}\right)$$

on the under, and of *d* on the upper, boom of a girder for a length E with reference to

{ their original ordinates;
{ " ordinates after permanent bending;

the measured

$$\begin{cases}\text{permanent deflection } b-\dfrac{a+c}{2}; \\ \text{elastic} \quad \text{"} \quad \text{"} \quad ;\end{cases}$$

the relative { permanent deflection.
{ elastic "

The ordinates *a*, *b*, *c*, *d*, and the length E, are to be measured in millimeters before the erection. The measurements with reference to permanent bending are to be made on each occasion before bringing on and after removing the trial load; those relating to elastic bending are to be made with the load on, and, 1, at rest; 2. moving at the rate of 10 meters per second. A space is also provided for remarks on the measuring instruments used, repairs carried out, the rivets, rust removed, renewed paint, &c. It is added that a considerable alteration in any measurement will point to the necessity of calling in an expert to discover the weak point.

With reference to iron constructions in general, it is noted that the task of making frequent observations on structures easily accessible to them should be remitted to specialists.

REPORTS OF ENGINEERING SOCIETIES.

Engineers' Club of Philadelphia.—December 3d, 1881. This meeting was the first held in the new rooms, although they were only partially ready for occupancy.

Officers were nominated to serve during the year 1882.

The matters of scientific interest presented, were as follows:

Mr. John E. Codman exhibited drawings of and described Nicholson's Fire Escape, which consists of a fire-proof brick tower, octagonal externally and cylindrical internally, with central shaft about 18 inches diameter, around which is formed a winding passage, of a U shaped section, 2 ft. 3 in. in width, with smooth or glazed surface, and inclined at angle of 35°, with retarding curves of less gradient. Fire-proof doors would connect with each floor and roof, and a vestibule with the surface of the ground below. It is intended that those escaping shall assume a sitting posture on entering the spiral and slide to the bottom, and it is claimed to be safer than other escapes for those unaccustomed to ladders, or weakened by fright or excitement.

Mr. Codman also exhibited a working model of Deschamp's Angular Shaft Coupler, by means of which shafting can be offsetted when bearings are displaced or bent to any angle, from 0° to 90°.

Prof. L. M. Haupt exhibited an Interpolating Scale, devised by Prof. W. S. Chaplin, of University of Tokio, Japan, by means of which any intermediate point of elevation between two known points, on a topographical plan, can be readily determined.

He also read a short discussion of Mr. S. C. Gant's scheme of Underground Railroads in Philadelphia, presented at last meeting. Prof. Haupt while decidedly favoring rapid transit and admitting the practicability of the construction proposed, considers Mr. Gant's estimate of the cost entirely too low, and, by comparison with the Union Tunnel at Baltimore, he estimates that that portion of the tunnel system which Mr. Gant estimates at $1,783,710 would cost $6,05 1,500, or about three and one-half times the original estimate, and even this he considers too low for the plan proposed.

Prof. Haupt also read a paper upon Railroad Cross-ties, touching especially upon the desirability of an iron tie, a model of which he exhibited at the last meeting.

Mr. T. Earl Collins exhibited and described a model of the Camerer Valve Motion.

Mr. Wilfred Lewis exhibited a movable head T square, the head of which is held very firmly in position by means of a cone clutch.

Mr. Howard Murphy opened the proposed discussion upon Passenger Elevators, by reading an account of the means and results of testing wire ropes and methods of attachment to cages, by Herr Baumann.

ENGINEERING NOTES.

A New Method of Communicating with Wrecked Vessels.—Messrs. Low and Duff, engineers, Dundee, have just made an important improvement in connection with apparatus for communicating with wrecked vessels. It is a new gun which they tried at Monifieth recently with marked success. The gun is 2 ft. long, with a bore of 2¼ in., and it is so constructed that the line which is to be fired from it passes through the back end of the gun. In the experiments which were made the line was shot 400 yards with 2 ozs. of powder, which would have sent it further had the line used on the occasion been longer. The cord is coiled in the form of a cop and put inside of a steel canister. This canister is fired out of the gun, and leaves the line streaming behind it. The distance to be covered is simply a question of size of gun and canister. The gun was sent to Birmingham and tested in the most thorough manner in the proof-house there. The twine used in the experiment was made of flax, and carried 200 lbs. dead weight with a length of 6 ft. of twine.

Pumping Petroleum.—It has for some years been the practice in the United States to transport crude petroleum by pumping it through long mains extending in some cases over hundreds of miles; but this system has not been established to any extent on the eastern side of the Atlantic. It is now, however, being carried out on an extensive scale in the Caucasus in South Russia, and Messrs. S. Owens and Co., of Whitefriars Street, have just completed an extensive pumping plant for this purpose. The plant consists of a number of small Blake pumps with 10 in. steam cylinders, 8½-in. pumps, and 12-in. stroke, which will be used to deliver the oil through branch services into the tanks from which the main pumps draw. For the main oil line Messrs. Owens have constructed three pairs of duplex Blake pumps with a new arrangement of valve gear, the valve of one pump of each pair being moved by connection with the piston rod of the other pump, and *vice versa*. The pumps have 24-in. steam cylinders with 30-in. stroke, the piston rods being double, and giving motion through a strong crosshead to a pair of single-acting plunger pumps with 4½-in. rams of phosphor-bronze, these pumps being intended to deliver the oil against a pressure of 1,500 lbs. per square inch. The pump cylinders are of close-grained cast iron with removable liners of phosphor-bronze, and the valves are of gun metal with leather faces, and are guided by long spindles on their upper sides working in strong gun-metal caps. The plungers are packed by hydraulic leathers. The arrangement of valve gear for the steam cylinders is very simple, and works with great smoothness, as we had an opportunity of seeing a few days ago, when Messrs. Owens were testing one of these pair of pumps in steam. We propose to illustrate the arrangement in an early issue, but meanwhile we may say that each steam cylinder has five ports, the two outer ones at each end being for steam admission, and the two inner ones for the exhaust. The slide valves are of the ordinary D pattern, and cushioning valves are provided for determining the stroke of the pistons, which can be easily adjusted to suit the speed and pressure. The two pumping engines forming each pair are mounted on massive cast-iron girder bedplates, the whole forming a thoroughly good and substantial job. The weight of each set of pumps complete is about 10 tons.

RAILWAY NOTES.

The Trans-Caspian Railway.—It is reported at Baku that the military Trans-Caspian Railway is about to be purchased by a firm well known in the region of the Caucasus, which is already at the head of numerous industrial and commercial enterprises in that province. The line is completely finished for a distance of 217 versts up to its terminus, Kizil-Arvat, and trains have been running on it for some weeks. It will not be extended further, but it is in contemplation to establish a tramway as far as Bami, so that there will be only 180 versts of road left in order to reach Askhabad. This Road is passable for vehicles, and is divided into four stages, to each of which there is a fortified station-house, where the horses necessary for the service of the Government are kept.

Portable Military Railways.—We have more than once advocated the liberal use for military purposes of light portable lines of railway, which if properly constructed can be efficiently employed even in districts where it is difficult to make a good ordinary road, and under these circumstances we are interested in noticing that a railway of this kind has just been sent out to Tunis for the use of the French army in connection with their march to Kairouan. The line in question is of 0.60 meter (23.6 in.) gauge, and has been constructed by M. Decauville, whose establishment at Petit-Bourg has lately been kept going day and night to complete the 50 kilometers (31 miles) of permanent way required by the end of October. The weight of rails which have been selected by the Minister of War are 14.1 lbs. and 19.2 lbs. per yard, and in the construction of the permanent way M. Decauville has introduced an improvement in the connection of the lengths, which enables the curved portions of the line to be used either right or lefthanded at pleasure. The line, which M. Decauville has named the "military pioneer railway," will serve for the transport of water, food, and munitions, and for carrying the sick or wounded. A small locomotive, the "Kairouan," weighing 3 tons, is being provided for service at the harbor, and to facilitate the unloading of the vessels.

British Railways in the Past and Present. — Attached to one of the balance-sheets of the Great Northern Railway there is a valuable comparative statement of the capital, revenue and other particulars of that railway over twenty half years. It becomes of interest, then, to trace the relative position of the railway so as to ascertain how the capital stands at the beginning and end of a decade; whether the line is as cheaply worked; and whether the invested capital is as productive. Broadly, it may be aid that ten years ago the capital of the Great Northern Railway was £19,876,000—or that part of it represented by shares and stock. In the total—with fixed charges added, that is—it was £22,300,000. It is now £33,970,000, so that there has been an increase, roughly, of fifty per cent. But the miles at work have not risen in like ratio—they were 491—they are now 601. And the gross receipts—£1,259,000 ten years ago, £1,664,000 now in the half year—have, it will be seen, increased much less than the fifty per cent. increase of the capital. On the other hand, the working expenses—£581,000 ten years ago, and £866,000 now—show an enlargement very close to that fifty per cent. which is that of the increase in the invested capital. In the last half of 1871 the working expenses were 46.13 per cent. of the earnings—in the last corresponding half year they were 52.06. For each train mile run the gross earnings were ten years ago 5.24s; but in the last comparative half-year they were only 4.52s. It is thus tolerably clear that the expenditure of capital in the ten years has not been so remunerative as before; and it is also plain that the working expenses have grown. It has to be borne in mind, in fairness, that there is a large amount of unproductive capital now, but so there would also be ten years ago. And, as the broad result, it is apparent that there has been a very great reduction in the dividends declared on the original capital—for that portion receiving fixed dividend has not had its rate affected of course. Hence it would appear that at the present time the Great Northern needs rest from heavy capital expenditure. It is only a type of several other railways which have expended large sums of money, but it is an emphatic type, for the dividends of few of the great companies have sunk so much in the decade as it has done. It is to be hoped that the completion of heavy works now progressing may enable the figures of future years to be more favorable.

ORDNANCE AND NAVAL.

The New Lyman-Haskell Cannon. — The Lyman-Haskell accelerating or multi-charge cannon is made with a succession of cylindrical chambers called "pockets" below the bore whose axes point toward the muzzle of the gun and form with its axes angles of about 60 degrees. In these pockets are placed the accelerating charges or powder that ignite after the passage of the projectile, which is started by the explosion of the initial charge in the gun chamber, in the usual manner.

Col. J. H. Haskell, of New York, adopting the accelerating principle first introduced by A. S. Lyman, also of New York, the inventor of the "Lyman accelerating gun," has made a number of improvements on it which are now the property of these two gentlemen jointly with their assigns.

The new Lyman-Haskell gun is expected to throw a projectile four calibers in length a distance of ten or twelve miles, leaving the gun at a velocity of 4,000 feet per second, which, it is claimed, can be done without the danger of bursting the piece, which would occur if the necessary force were generated by the explosion of a single charge

A number of tests of the principle have been made; notable among them are those at the Washington Navy Yard, where a 2½ inch accelerating gun was tested in competition with a 5-inch Whitworth (English) gun. The target consisted of 5 inches of iron plates backed with 18 inches of oak timber. At a distance of 200 yards, the projectile from the accelerating gun went entirely through this target and landed 100 yards beyond it, while the English projectile fired from the same distance, with double the charge of powder, failed to penetrate the same target. Gen. John Newton, U. S. Engineer, finds that a 10-inch accelerating gun will be as efficient as the 81-ton Armstrong, while a 12-inch accelerating gun will be more powerful than the 100-ton Armstrong.

On the 24th of October a casting was made at the "Scott Foundry" of the Reading Iron Company, for a 6-inch Lyman-Haskell gun. This casting is made without cores, and is to be bored for the pockets and will form the breech section of the gun. Its weight is upward of 50,000. It was cast from two reverberating furnaces charged with 56,000 pounds of cold-blast charcoal pig-iron of the following brands:

Brands.	No. 1 Furnace. Pounds.	No. 2 Furnace. Pounds.
Maiden Creek ...	3,680	2,745
Juniata..........	3,670	2,745
No. 2 Richmond..	15,425	11,555
Falling Spring and No. 1 Franklin	4,775	3,575
Remelted Iron....	4,545	3,400

The section to form the muzzle portion will be cast separately, and firmly joined by socket to the breech section. The whole is to be then lined with steel in one continuous cylinder for the bore and smaller ones for the pockets.

The weight of the gun when completed will be 25 tons, with a total length of 24 feet 11½ inches. It will have a bore of 6 inches, and will carry a ball weighing 150 pounds, of 4 calibers length. Eighteen pounds of hexagonal powder will be used in the breech, with 28 pounds of powder of finer quality in each of the four pockets, making a total of 130 pounds. This is one hundred pounds more of powder than is ordinarily used, and by means of this system of explosion, the projectile will have a penetrating power as 1½ is to 4, compared with other cannon. The initial velocity of the ball will be 4,000 feet in a second, while that of other guns is from 1,500 to 2,000. The ball is calculated to penetrate two feet of wrought iron at a distance of 200 yards. By means of the successive discharges of powder from the four pockets the pressure upon the ball will be maintained, thus giving it its great velocity, which will carry a ball twelve miles. The explosion takes place in tough steel, supported by the strongest cast iron. After its completion, which will be in several months, the gun will be taken to Sandy Hook, where it will be thoroughly tested in the presence of army officers and distinguished scientists.

Hydraulic Machinery on Board Ship.—Messrs. Brown, Bros. and Co., of Cannon Street and Edinburgh, have recently fitted up the steamship Quetta with the most elaborate and complete set of hydraulic machinery ever put into a ship. A pair of engines capable of working up to 100-horse power is employed to maintain a constant water pressure of 700 lbs. on the square inch, kept under a steam accumulator, and from the accumulator pipes are led to all parts of the ship where power is required, The Quetta belongs to the British India Line, and has a gross tonnage of 3,302 tons. On the forecastle is a 15 ton hydraulic capstan driven by four pendulous hydraulic cylinders, collectively of 50-horse power. A similar but less powerful capstan is placed at the other extreme end of the mains on the poop. The ship is steered from the bridge amidships by a wooden tiller similar to that of a small yacht. By moving the tiller, a slide valve is opened, which is in connection with the hydraulic rams and cylinders aft. When the valve is opened to either port or starboard cylinder, a corresponding movement of the rams and rudder takes place, strictly controlled, however, by mechanism, which prevents the helm from running away from the steersman. The rudder itself is connected with the rams in such a way that the latter obtain an increasing leverage as the rudder is being put hard over, when this leverage is, of course, most needed. A hydraulic cylinder with a similar arrangement of valve and automatic controlling levers is applied to the main engines, by which they can be reversed or stopped in three seconds by a single reversing lever. The water-tight door of the shaft tunnel is also opened and closed by a hydraulic cylinder, the valve of which is near the deck, so that in the event of an accident this door can be instantly closed. In the stokehole close by is fixed a hydraulic hoist for lifting the ashes. The most valuable application of the Quetta's hydraulic machinery is the loading and unloading of the cargo. It may be mentioned that at Colombo, in the course of the single voyage which the Quetta has already made to Calcutta and back, 1,250 tons of rice were discharged in ten hours. On the Quetta's deck there are four hatches Those at the extreme ends fore and aft are fitted with single hydraulic hoists, the two main hatches having double hydraulic hoists. Each of these hoists is capable of raising a ton and a half through a height of 70ft., at a speed of 5ft. per second. The hoist consists of hydraulic rams, fitted into cylinders, and working through stuffing boxes. Each ram is connected to three chain pulleys, while the other three are carried by the cylinder base-plate. A foot of rise in the ram raises the load 6 feet. The water is admitted to the cylinder by a slide-valve worked by a single lever, whereupon the load is lifted; while, by reversing the lever, the water is allowed to escape and the load to descend. An ingenious arrangement prevents the load from running from one extremity to the other, through the unskilfullness of the driver, and thus risk damage to the cargo. A wholly inexperienced man can thus work the apparatus without any danger. The hoists will discharge cargo at the highest speed of 5ft. per second and be brought to a state of rest automatically at any position required. To summarize the advantages of the Quetta hydraulic machinery, a pair of engines in one place do, with no noise and half the consumption of fuel, the work usually performed by perhaps a dozen donkey engines; while about £30 or £40 a voyage is saved in wear and tear. The increase of speed obtained in loading and discharging cargo practically insures a quicker voyage. The rapidly-working machinery necessitates double gangs of men in the hold; but, though the hands are more numerous, they are paid for a shorter time; and the cost of labor per ton of cargo is thus less than usual. The prime outlay is considerably greater than under the ordinary system; but it is calculated that in at most three years the extra expense will have been saved.

The dimensions of the new ironclads of which the Italian Admiralty have recently ordered the keels to be laid down within the month, one in the dock yard at Spezzia and the other at Venice, are as follows: Length, 100 meters: immersion, 7 meters 65 centimeters; displacement, 10,000 tons; engines, 10,000-horse power, giving a presumed velocity of sixteen miles per hour. The cuirass, which is to extend over a length of 55 meters, will be 45 centimeters thick and 40 at the bulwarks and turrets. The guns are to be of the kind which, three years hence, when the ships are ready for them, shall have been found by experience and experiment to be the most useful.

On the afternoon of the 10th Nov. an iron screw steamer, the Zuid Holland, of 2,270 tons gross register and 220-horse power nominal, for the Rotterdam Lloyd's Mail Line between Holland and Java, was launched from the yard of Messrs. Raylton, Dixon, and Co. The dimensions of this vessel are: Length, 311ft.; breadth, 37t.; depth, 27ft. She is classed 100 A1 at Lloyd's, and will be fitted with cabin accommodation for first-class passengers in large deck-house, specially arranged for good ventilation and containing large saloon panelled in polished marble. This vessel is the sixth which has been built for the same line by Messrs. Raylton, Dixon and Co., and is a sister-ship to the s.s. Utrecht, also trading between Rotterdam and Java.

Guns versus Armor.—A lecture on the above subject, but bearing the title of "The Attack of Armor-clad Vessels by Artillery," was delivered in the Theater of the Royal Artillery Institution, Woolwich, on October 19, by Captain C. Orde Browne, late Royal Artillery. General Sir Collingwood Dickson, V.C., K.C.B., presided, and there was a large attendance of naval, artillery and engineer officers and civil engineers. The lecturer pointed out the necessity for the recognition of the nature and thickness of an enemy's armor in order to decide whether to make the primary attack (*i.e.*, the attack on the armored structure containing the vital parts of the ship) or the secondary attack (*i.e.*, the attack on the less protected or unprotected parts). Dealing first with the primary attack, he showed that where steel was used as armor the blow was distributed through the mass of the steel, and therefore, that it had great power of resistance against a single blow, though it was liable to succumb to the continued fire, even of inferior guns; and he pointed out that this was not a question of penetration, but of shattering, the effect being probably proportioned to the stored-up work, irrespective of caliber. He showed that in compound or steel faced armor the effect was modified, and he mentioned the case of a compound target of Brown's, at present at Shoeburyness, which had resisted the fire of four rounds from 9-inch guns, and one from a 38-ton gun, three of the former containing the same amount of stored-up work as the single round from the latter gun; so that a sort of comparison became possible between the effects of a given quantity of work delivered in one heavy or three light projectiles. He said that while in the case of steel the blow was distributed through the mass, in the case of iron armor the iron suffered locally only, and hence it was either penetrated completely or was practically uninjured, and did not suffer seriously from the continued fire of guns unable to perforate it. Hence the great significance of the development of new type guns, steel shells, and gun-cotton charges. From the instance of the Krupp 9.45-inch 18-ton gun at Meppen, which perforated 20 inches of iron without injury to the projectiles, the lecturer deduced that fire might be carried into the most strongly-armed portion of any English armor-clad, except the *Inflexible*, by a new-type 18-ton gun. He showed how important it was to ascertain the limit of thickness of iron which any given gun may penetrate at any range, and gave the following rule for ascertaining it—viz., that a shot will penetrate armor one caliber thick for each 1,000 feet velocity. The results obtained by this rule were compared with those taken from Col. Inglis's diagram, and shown to be nearly approximate. With regard to "secondary attack," he referred to the case of the deck being struck from guns in positions of command, particularly in the case of ships engaging nearly head on, and pointed to the necessity for using common and shrapnel shell in attacking unprotected portions. The conning power and the funnel were dealt with under the head of "secondary attack." The case of the *Huascar* was referred to, it being noticed that her conning tower was destroyed, and the staff of the vessel killed. The vessel kept her stern, as being the weakest portion, out of fire as much as possible, and manœuvered so as to keep between the adversaries she endeavored to ram, and, generally speaking, showed great skill, except in the matter of her fire, for neither in her engagement with the English unarmored ships, nor afterwards with the two Chilian vessels, did she succeed in ever hitting anything to any purpose. With regard to the funnel, the lecturer pointed out that it afforded a natural mark for light guns, in the hope of reducing the steam-power of a ship.

The hopelessness of this endeavor was shown by calculating the effect of a funnel cut down from 50 feet to 30 feet, which would only result in reducing the speed one knot in 12. The lecturer then referred to different types of vessels, models of which he exhibited—viz., the *Glatton*, the *Inflexible*, the *Admiral Duperre*, and the *Polyphemus*, and showed the mode of attack in each case. As to ratio of weight of guns to tons of displacement, it was pointed out that the French ships have generally more pieces, and these of lighter weight, than the English, the average number of heavy guns in each of our first-class turret ships being 5.1, and in each first-class broadside 11.1, while in French first-class ships it is 15.3. The lecturer remarked that the total weight of metal in ordnance carried by each ship may be shown by the number of tons displacement per ton of gun—*i.e.*, English turret first-class, 56.1, broadside 43.5, French first-class 39.5, second class 52.3. The advantage of the all-round fire of the turrets might enable an English ship to bring a great weight of artillery into action, but it was a question whether the greater number of guns carried by broadside ships did not deserve more consideration than formerly, since the great development of power consequent on the introduction of new-type guns. Very heavy guns had special power against chilled-armor, which they might wreck in a way that would not be possible with the same power distributed among a number of lighter guns. This question concerned our navy more than our land artillery, seeing that the French, the Germans, the Russians, the Danes, the Dutch, the Spanish, and the Portuguese had forts of chilled iron on their coasts—a species of armor which England had not adopted, or even tried. To lead to discussion, the lecturer suggested two questions—first, whether we do not need medium new-type guns introduced as far as possible into the armaments of our ships and forts; and, second, whether the secondary attack of the weaker parts of armor-clad ships did not deserve more attention than it had hitherto received. The lecture was followed by a discussion.

BOOK NOTICES.

Publications Received.

Extra Census Bulletin—The Areas of the United States. Henry Gannett, E.M. Washington: Government Printing Office.

Dundee Street Railways, By Andrew Greig, M.I.C.E. Published by the Institution of Civil Engineers.

Report of Experiments on the Resistance of Thick Cast-iron Cylinders to Internal Pressure. By Colonel T. T. S. Laidley. Boston: Mills, Knight and Co.

Graphics of Rectangular Bridge Trusses. By Theo. Kandeler. Chicago. L. Schick.

Monthly Weather Review for October.

Elementary Lessons in Electricity and Magnetism. By Silvanus P. Thompson, B.A., F.R.A.S. London: Macmillan and Co. Price $1.25.

A new book on so important a topic by so eminent an authority will be welcome to a host of students. It is designed for the multitude of learners who are eager to find the logical connection between the teachings of the text-books in common use and the practical developments of electrical and magnetic science, which now occupy so large a share of the public attention.

How completely the author covers this important field of research, may be inferred from the following list of chapter headings:

I. Frictional Electricity.
II. Magnetism.
III. Current Electricity.
IV. Electro-statics.
V. Electro-magnets.
VI. Measurement of Currents.
VII. Heat, Light, and Work from Currents.
VIII. Thermo-Electricity.
IX. Electro-Optics.
X. Induction-Currents.
XI. Electro-Chemistry.
XII. Telegraphs and Telephones.
Appendix—Electrical Units and Exercises.

New System of Ventilation. By Henry A. Gouge. Fourth Edition, Enlarged. New York: D. Van Nostrand. Price $2.00.

The estimate of the previous editions of this work, which has led to a fourth one, is evidently based upon the thoroughly practical character of the author's suggestions.

The work is really a treatise upon one of the most important branches of sanitary engineering. Methods of replacing foul air by fresh air in all enclosed habitable places, as well as in all places designed for storage of perishable things are presented and urged as a necessary concomitant of an advance in civilization.

The essay is divided into two parts: Ventilation, Its Importance and Necessity; and What Is, and What Is Not Ventilation.

Report of the U.S. Commissioner of Education for the Year 1879. Washington: Government Printing Office.

This report is of interest chiefly to educators. It bears evidences of careful and laborious labor in compilation, and will be regarded with much interest by the few who are responsible for the methods of education, and will be kept for reference by many who have occasional use for statistics.

Sewer-Gases and How to Protect our Dwellings. By Adolfo de Varona, M.D. Second Edition Revised and Enlarged. New York: D. Van Nostrand. Price 50 cents.

That a second edition of this book should be so soon demanded is a natural result of the quality of the early edition and the public interest in so important a subject.

The author deals briefly and directly with the following topics:

Necessity of Sanitary Measures.
Sewer Gases.
Relation of Sewer Gases to Disease.
Sewers—Their Proper Size.
Inclination of Sewers.
Material of Sewers.
Ventilation of Sewers.
House Drains.
How Gases Enter the Dwelling.
How to Protect our Dwellings.
Subsoil Drainage.
Relations of Ground Water to Disease.
Ventilation of Dwellings.
Disinfectants.

The illustrations are numerous and good.

L'Astronomie Pratique et Les Observatoires en Europe et en Amerique. Par C. André et H. Angot. (Fourth Part). Paris: Gauthier-Villars. Price $1.50.

Something more than half of this little book is devoted to the meteorological stations of the United States. The remaining portion relates to the astronomical observatories of South America, of which and their equipments a brief descriptive account is given.

Dictionnaire des Arts, Manufactures et de L'Agriculture. Par Ch. Laboulaye. Paris. Price $43.20.

This extensive work fills four large volumes of about one thousand pages each.

The illustrations are very numerous and admirably adapted to the purpose of aiding in the description of processes and machines.

Important subjects are expanded to the magnitude of ordinary treatises. Thus "Filtration" covers sixteen pages and the steam engine seventy.

MISCELLANEOUS.

Celluloid may be used for preserving engravings, *clichés*, and stereotypes. The process employed for this purpose, we learn from *La Nature*, consists in taking an impression of the engraved block by means of a special cement, which receives the impression and rapidly hardens. The presses used to take the first impression are heated, and the sheet celluloid is then used to take the counter impression from which to print. Celluloid thus gives an exceedingly clear reproduction of specimens of lace and other fine work with difficulty obtained in any other way.

A method for determining the total solid matter in solution in different waters is described in the *Journal* of the Chemical Society, by Dr. Mills. The method is based on the fact that if a small glass bead with an attached weight is allowed to ascend in a saline solution of known strength, it will rise more slowly, the greater the amount of solvent present. Experiments are given showing that the rate of ascent is also dependent on the nature of the soluble matter, *i. e.*, on the viscosity of the solution. For detecting variations in the solids in the same water, for preparing standard solutions, &c., the bulb method is likely to be useful. Experiments detailed in the same paper lead Mills to regard the specific gravity of a potable water as a direct indication of the quantity of total solids in solution.

An electro-magnet of enormous dimensions has lately been made by Messrs. von Feilitzsch and Holtz for the university of Greifswald. The case is formed of twenty-eight iron plates bent into horseshoe shape, and connected by iron rings so as to form a cylinder 195 mm. in diameter. The height is 125 ctm.; the total weight 628 kilogs. The magnetizing helix consists of insulated copper plates and wires having a total weight of 275 kilogs. With fifty small Grove elements the magnet will fuse in two minutes forty grammes of Wood's metal in the Foucault experiment. The plane of polarization is rotated in flint glass after a single passage. The core of the largest magnet hitherto known, that of Plucker, weighed 84 kilogs. and the wire 35 kilogs.

Clerk's Gas-engine.—Hitherto gas-engines using compression before ignition have made at most one impulse for every two revolutions. It is evident that if an impulse could be obtained for every revolution a great increase of power would result. Many fruitless attempts have been made to accomplish this desirable end, which has, however, at length been effected in Clerk's gas-engine, which we illustrate on the next page. One of these engines is being exhibited at the Paris Electrical Exhibition by Messrs. Thomson, Sterne, & Co., of 9, Victoria Chambers, Westminster. This engine has a motor cylinder, 6 inches in diameter, and a light displacer cylinder of a larger diameter. The stroke of the piston is 12 inches, and it is connected to a crank by the usual rod. As the pressure in the displacer cylinder never exceeds 5 lbs. per square inch, the connections are very light, and it is driven from a pin on one of the flywheel arms. The displacer crank pin is in advance of the motor crank and at right angles to it. When it moves forward, the combustible mixture of gas and air is drawn into the displacer cylinder during the first half of the piston's stroke, at which point the gas is cut off and air only admitted for the remainder of the stroke. The displacer on its return stroke discharges its contents through a lift valve into the motor cylinder, the piston of which is hot at the out end of its stroke and has uncovered an annular port in the cylinder communicating with the exhaust pipe. The heated products of combustion discharge through this port until the pressure in the cylinder has fallen to that of the atmosphere. The air from the displacer then entering at the back end expels the remaining hot exhaust, and passes in part through the exhaust pipe. The cylinder is now filled with pure air, and when the combustible mixture enters, displacing in turn the air, the cylinder contains nothing but an ignitable mixture and air. The motor cylinder in its in-stroke compresses the mixture into a space at the end of the cylinder, the pressure rising to 45 lbs. above the atmosphere, when ignition takes place, and the pressure now ranges from 200 to 250 lbs. per square inch above the atmosphere. The piston moving forward, the pressure gradually falls, and at the end of the stroke the exhaust discharges at about 30 lbs. above the atmosphere. This cycle of operations is repeated at every stroke. In larger engines the terminal pressure before exhausting is very much less than 30 lbs., being sometimes as low as 5 lbs. above the atmosphere; but this is obtained by an arrangement which allows of a greater expansion. The volume swept through by the displacer piston is greater than the combined volume of the motor cylinder and the space at the end of it, into which the ignitable mixture is compressed. As half of its charge is pure air, it follows that at every stroke of the engine the whole products of combustion are discharged and replaced by pure cool air before any combustible mixture is allowed to enter. This arrangement produces the greatest certainty in the action of the engine.

Premature ignitions sometimes arise from the combustible mixture entering the cylinder while it still contains products of the previous combustion, and being ignited at the wrong time, either by flame still existing in the cylinder, or by sparks on the walls of the combustion chamber, due to the ignited carbon from the decomposition of the oil used in lubricating. To prevent these irregular ignitions it is necessary to clear out any hot burned gases, and to secure a sufficiently low mean temperature of the surface of the cylinder and combustion chamber to render the existence of sparks impossible. In the engine under notice these conditions are secured by the use of the displacer cylinder, as the charge is not compressed in the cylinder, but merely passed into the motor cylinder at such a pressure above the atmosphere as is necessary to lift the valves and to discharge the exhaust. It therefore follows that it may be made of any size found necessary to pass the volumes of air for clearing and cooling. This device is the essential feature of the engine, rendering, as it does, an ignition at every stroke possible. The engine may thus be continuously worked up to its full power, igniting at every stroke without irregularity or stoppage. The arrangements for admitting gas and air, for cutting off the gas at the proper time, for igniting, and for exhausting, are of a simple and efficient character, and the engine is substantially made and well finished. We are informed that the engine exhibited at Paris gives 6-horse power by the brake at 145 revolutions, and indicates about 10-horse power. As the cylinder is only 6 inches in diameter, and the stroke 12 inches, it will be seen that this is a very powerful engine. It is, moreover, one which promises well to assist materially in the practical development of electric lighting.

As the result of an investigation of the statistics of the rate at which barometric changes traverse the British Isles, by Mr. G. M. Whipple, F.M.S., superintendent of the Kew Observatory, he concludes—(1) That the average rate of horizontal motion of barometric changes in their progress across the British Isles is about 58 miles per hour; (2) That the mean rate does not vary to any considerable extent from year to year; (3) That the maxima travel with somewhat greater velocity than the minima; (4) That the rate of horizontal motion is slightly diminished as the change passes northward. This is also proved by the fact that the man. velocity along the Valentia—Aberdeen, track, is slightly below that over the Falmouth—Leicester, track. By far the greater number of barometric changes traverse the country at rates between 30 and 60 miles per hour, but transits at the higher velocities are somewhat infrequent. The mean southwest - northeast velocity of 58 miles per hour, if resolved into north and south and east and west velocities by the ordinary method of the parellelogram of velocities, gives a resulting movement of 38 miles per hour in a west-east direction, which, he says, may be safely taken as the normal rate at which barometric changes traverse the British Isles.

The periodicity of rainfall formed the subject of an inquiry by Mr. G. M. Whipple, superintendent of the Kew Observatory, and by him a paper was communicated on the subject to the Royal Society early this year. From all the available statistics extending back with more or less completeness for many years, he finally deduced a table which shows that in no one case is there any indication of a period of any integral number of years from five to thirteen inclusive running through them. Hence, whatever period of variation in rainfall there may be, coincident with fluctuations in the spotted surface of the sun, either of ten, eleven, or twelve years, this method of treatment shows it to be completely masked—in a long series of observation—by other variations. The discrepancies exhibited in the first tables obtained made it very desirable to extend the field of inquiry, by including as many observations in the discussion as possible. Eventually he was able to collect ten series, which increased the total number of years of observations used in the discussion to 978. The result of the extended investigation in no way affected the conclusion pointed out by the observations previously treated—viz,, that taking the series of annual totals directly as they stand, there is no marked indication of the presence of a short cycle to be found. There are a few exceptions, in all of which cases the coincidences but slightly preponderate over the non-coincidences. Again, the curves of variation differ widely for the same epoch in localities comparatively close together.

Nickel was at one time deemed infusible, and at best only metalloid. It is many years since that its infusibility was conquered, and now pure nickel may be procured in almost any form. The latest achievement in this direction appears to be the successful reduction of iridium from its ores by Mr. John Holland, of Cincinnati. By mixing a certain percentage of phosphorus with the ore, the metal can, according to a new American monthly magazine entitled *Progress of Science*, be melted and run into bars; the phosphorus can then be eliminated by heating the bars to a white heat in the presence of lime. The metal cannot be forged or filed into shape, but is cut with a revolving copper disc and emery and oil or water. Its use has been suggested as electrodes in lieu of carbon in the electric lamp.

THREE machines are exhibited in the Paris Exhibition which must be of great interest to all electricians, and which will hereafter be of historic importance. These are three magneto-electric machines, constructed by Professor Pacinotti, of the Cagliari University, and well known to fame by his invention of the ring-shaped armature as used in the Gramme and Brush machines. The first machine of this kind, made by Pacinotti at Pisa in 1860, is exhibited, as well as a second machine made by him in 1873. The second is a dynamo-electric machine in which a shunt is employed so that the current is divided between the fixed electro-magnet and the resistance, two pairs of brushes making contact with the different segments of a commutator. The third machine exhibited was constructed in 1878 from a model made three years previously, and is a direct application of Arago's experiment showing the deflection of the magnetized needle by a revolving copper disc, the electric effect being derived from the induced current in the copper disc.

ACCORDING to MM. Behm and Wagner's *Bevölkerung der Erde*, Europe has now a population of 315,929,000 inhabitants; Asia, 834,707,000; Africa, 205,679,000; America, 95,405,000; Australia and Polynesia, 431,000; the Polar regions, 82,000; giving a total for the globe of 1,455,923,000, being an increase of 16,778,000 according to the latest known censuses. At the end of 1877 Germany had a population of 43,943,000; Austria and Hungary—1879—of 38,000,000; France—1876—of 36,900,000; Turkey in Europe, of 8,860,000; Russia, of 87,900,000. In Asia, China possesses 434,900,000 inhabitants; Hongkong, 134,144, Japan, 34,300,000; according to the census of 1878. The British possessions in India number 240,200,000 people—an estimate made before the census of this year—the French possessions 280,000; Cochin China, 1,600,000; the East India Islands 34,800,000; the islands of the South Sea, 878,-000. The area of Africa is estimated at 29,383,000 square kilometers, divided as follows:—Forests and cultivated land, 6,300,000; savannahs, 6,235,000; steppes, 4,200,-000; deserts, 10,600,000. The inhabitants of British North America number 3,800,000: of the United States, 50,000,000; of Mexico, 9,485,-000; and of Brazil, 11,100,000. The Polar regions extend around the Arctic circle with an area of 8,859,000 square kilometers, and the Antarctic regions about 600,000. The population of the former is small, with the exception of Iceland, which has 72,000, and Greenland 10,000.

AN extensive landslip has occurred on the side of the river Severn, at Broseley. One of the hills which border the river at this point has recently given away, falling towards the river, and carrying with it the Severn Valley Railway, which runs through the hill. Within a short period the railway has been lowered by the slip to the extent of five yards, thereby necessitating continual attention and expense on the part of the Great Western Railway Company in keeping up the level. The slip has now assumed a serious aspect, and at one point, near Jackfield, the river has been so narrowed by the fall of earth as to be scarcely navigable. The fall continues daily, and is placing in jeopardy the buildings upon the hill. With the view of taking immediate measures for preventing loss of life, or any further damage to property, a trial shaft has been sunk for the purpose of ascertaining the depth of the slip, and it is thought probable that a scheme may be adopted to prevent the slipping of the hill. A report upon a slip at this point was made to the House of Lords some time since. The slip is one hundred yards in breadth, and upon the land affected there is a church, as well as other buildings.

A BLOCK of stone, 65 ft. long, 30 ft. wide by 10 ft. thick, has been quarried on Spoon Island, Queens County, New Brunswick.

THE Phosphor-Bronze Company, Limited, has been awarded the highest order of merit and gold medal at the Adelaide Exhibition, for phosphor-bronze, and articles made therefrom.

THE engineer of Ottawa, has reported against the proposal to light the city by electricity. The present cost of doing so by gas is stated to be £2546. Electricity generated by steam would cost £4960, and, if water power were utilized, £3200.

AT the Nepean—Adelaide—Waterworks 350 men had, at receipt of last mail, struck for higher wages; they demanded 8s. per day, instead of 7s. 6d. they were receiving, and they also required two intervals during the day of a quarter of an hour each for smoking.

IT seems that the earthquake in the Abruzzi, was far more destructive than was at first thought. The Commission of Succor reports that of 1340 houses, seventy-nine must be rebuilt, and 618 have been rendered uninhabitable, so that about four-fifths of the population are without shelter.

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VAN NOSTRAND'S

ENGINEERING MAGAZINE,

COMMENCED JANUARY, 1869.

Published on the 20th of the month at $5.00 per year.

The January number of this MAGAZINE, for the year 1882 begins the Twenty-sixth Volume. Beginning as an Eclectic Journal, and presenting almost exclusively matter selected from current literature, it has gradually become the chief medium through which the leading writers on engineering subjects can best present their original essays to American readers.

The attitude of the MAGAZINE has been, and will continue to be, that of a journal of original and selected papers upon subjects relating to modern advanced Engineering. Theoretical and Practical Essays are alike presented in its pages, although the latter largely out-number the former, as best suited to the tastes and demands of the American Engineers. Some of the most valuable contributions to the literature of technical science within the last few years have been first presented in these pages.

Among the more extended original contributions to the later volumes may be cited Transmission of Power by Wire Ropes—Momentum and Vis Viva—Rapid Methods of Laying out Gearing—Strength of Long Columns—Suspension Bridges of Any Degree of Stiffness—Acoustics in Architecture—Continuous Girders—Geographical Surveying—Mathematical Theory of Fluid Motion — Thermodynamics—Cable Making for Suspension Bridges, &c., &c.

To the above may be added the following valuable essays, translated from foreign sources, which have first appeared in these pages: Linkages and their Applications—The Origin of Metallurgy—The Theory of Ice Machines—Incandescent Lighting.

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VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLVIII.—FEBRUARY, 1882.—VOL. XXVI.

EARTH PRESSURE.

By WM. CAIN, C.E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

In the October, 1881, and succeeding numbers of this magazine, is published a paper presented to the Institution of Civil Engineers, by Mr. Benjamin Baker, C. E., on "The Actual Lateral Pressure of Earthwork," in which is given an account of a number of direct and indirect experiments on the subject matter, together with Mr. Baker's comments, and comparison of results with a certain theoretical formula, from which it is concluded that the formula gives results much larger than the true ones, even in the ratio of two to one in most cases.

The experiments, some of which were made half a century ago, are very instructive, and should be carefully examined by all engineers who may have occasion to design retaining walls or any kind of structures for resisting the pressure of earthwork.

With this object in view, the writer set to work to test another formula than the one given by Mr. Baker, and with materially different results. This formula includes the friction between the wall and the earth at its back (which is always exerted when a wall moves over and is very appreciable in amount), and is, in one shape or another, the favorite method in use in France and Germany.

The reader is referred to an article by the writer on Retaining Walls, published in the April, 1880, number of this magazine, in which a general formula is found after Weyrauch, from which in turn is deduced for the case of a mass of earth of unlimited slope, Rankine's formula; the direction of the earth thus against a retaining wall is then carefully examined and an attempt made to harmonize the teachings of the two schools, one of which claims that the direction of the earth thrust is always parallel to the top slope of earth, the other claiming that this thrust is inclined at an angle φ of friction of earth on earth, to the normal to the wall. Rankine may be regarded as the originator of the first school, and such men as Scheffler and Winkler as representatives of the second.

It must be observed, at the outset, that all theories are confessedly imperfect, for they suppose the earth *homogeneous* and of the *same density* from top to bottom, *incompressible* too, though it is well known how much embankments shrink, *devoid of cohesion*, *free from water* and *vibrations*, and subject only to the laws of gravity and friction.

So that all we can do is to test our formula, framed from this simple data, by experiments, and see if it can be made to answer the needs of practice, and to what extent.

In the article referred to, the point is made that for a perfectly immovable wall, and earth that has not settled behind it, the direction and amount of the earth thrust is as given by Rankine; but where the earth has settled appreciably behind the wall, or the wall is on the point of overturning or sliding, then the rubbing of the back of the wall against the earth causes friction, so that the earth thrust must be taken as making an angle φ (or φ' = angle of friction of wall on earth, when $\varphi' < \varphi$) with the normal to the wall.

Let us suppose, *e.g.*, that as the earth is first being deposited against the wall that the thrust by Rankine's formula is exerted. As the earth is filled in, the center of pressure on the base of the wall gradually moves towards the outer toe, causing a greater compression there than elsewhere, and the top of the wall very gradually moves forward, causing friction between the earth and wall at its back, which as gradually increases until its maximum value is attained; at any rate when settling of the earth begins, and this friction will always be exerted at the back of the wall unless destroyed by vibration and rains, or that general consolidation of the bank due to chemical and cohesive affinities, and the compression caused by gravity which manufactures solid clays out of loosely aggregated materials, and often causes the bank even to shrink away from the wall intended to support it. It is evidently then a matter for experiment to decide how much of this friction can be depended on in practice to add to the stability of the wall.

For the corresponding direction of the thrust there is a certain wedge of maximum thrust, different from that for an immovable wall, backed by incompressible materials; the plane of rupture lying nearer the horizontal in the first case than in the last. As a consequence, we shall find that walls that are unstable by Rankine's formula, are perfectly stable by the more correct formula that takes into account this wall friction.

It is to be observed, however, that although the hypothesis of a *plane* surface of rupture has been established, in the article referred to, for the case where the thrust is parallel to the top slope, yet it has not been established for the case where the thrust makes the angle φ or φ' with the normal to the wall, and it is probably incorrect to a certain extent; so that the formula is at best, even for favorable materials (as dry sand devoid of cohesion) only a near approximation.

In steep cuttings, the action of water is constantly bringing down masses of earth whose surface of rupture is curved, more or less vertical at the top and approaching a cycloid somewhat in section.

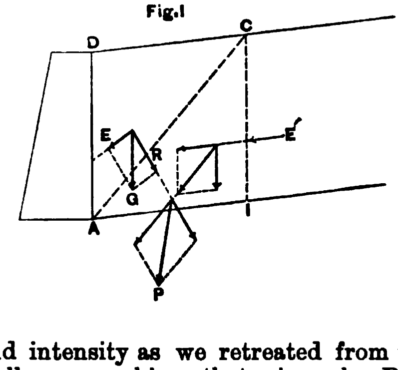
Mr. W. Airy states that he has found a mathematical expression for this curve, but remarks that the constants of cohesion and friction are so variable that its knowledge is of little practical utility.

In the practical formulas, cohesion is neglected, partly on this account and partly because it renders the formula so complex.

If we start out then with such hypotheses as have been stated, which evidently apply, approximately, only to new embankments, and not to old cuttings at all, we may as well for the sake of simplicity assume the surface of rupture *plane*, especially if the results are found to agree sufficiently well with practice.

It was stated in a former article, that supposing the thrust against the wall to be that given by the wall-friction method, that it would be changed in direction

Fig. 1



and intensity as we retreated from the wall, approaching that given by Rankine for a mass of earth of unlimited extent.

Let us first see how this difference in the horizontal components of the thrust is to be provided for.

In the figure, let the straight line AC represent the surface of rupture.

Call the weight of the prism of rupture

ADC, G, the earth thrust against the wall E, and that against the plane of rupture R.

In consequence of the friction exerted against the wall AD by the earth, from their relative movement, the thrust E makes the angle φ' of friction of wall on earth with the normal to the wall, unless φ' is greater than φ, when a thin slice of earth will adhere to the wall, and the friction of this with the adjacent earth will correspond to the angle φ, which is now the angle the thrust makes with the normal.

Similarly the resultant R on the plane AC makes the angle φ to the normal.

So that laying off G = weight of prism ADC, we find E and R by drawing the parallelogram of forces whose sides are parallel to their directions.

By Rankine's method the direction of E would be parallel to $\overline{DC}$, and it will be found that the plane of rupture $\overline{AC}$ lies nearer the vertical, and that the horizontal component of the thrust is larger than in the previous case. It would certainly seem reasonable to suppose that, as we retreat from the wall this horizontal component approaches gradually that given by Rankine for a mass of earth of unlimited extent.

So that on a vertical plane $\overline{CI}$ of the same depth as $\overline{AD}$, the thrust E′, should have a greater horizontal component than E and should be more nearly parallel to $\overline{DC}$. For the object in view it will suffice to combine E′, with the weight of the prism ACI = G and this resultant in turn with R to find the resultant P of the thrust on the plane AI. P is, of course, inclined to the left of the vertical, and its horizontal component is the difference between the horizontal components of E′ and E; so that the surface AI must exert sufficient friction to destroy this difference, which it is perfectly capable of doing; therefore no objection can be urged on the score of an unaccounted-for difference in horizontal thrusts, and the two theories are thus rendered perfectly consistent with each other. If we had assumed E and E′ equal and parallel to the top slope, the resultant pressure on the plane AI would have been vertical; the starting point of Rankine's theory.

This action of the surface AI, in taking up a portion of the horizontal thrust, is analogous to the case of an ordinary road embankment, which, in consequence of symmetry about the plane AD exerts a *horizontal* thrust there. This thrust, when combined with some part of the weight of CAD, gives the final resultant

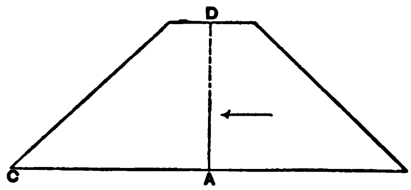


Fig.2

on AC, which ground surface must thus resist by friction the whole of the horizontal thrust.

It may occur to others than Mr. Trautwine (see his Engineer's Pocket Book p. 336) that the proper way to take account of the friction between the earth and wall, is to combine it with the thrust, as given by Rankine, for the total thrust against the wall; but such a resultant thrust will not be found to correspond to any wedge of maximum thrust. The proper direction of the thrust E must be assumed at first and the corresponding wedge of maximum thrust obtained.

The reader is referred to the article in the April, 1880, number of this magazine for a demonstration of the formula applicable. It is proper to state, that Weyrauch, whose general formula we shall adapt to the case in question, agrees with Rankine as to the direction of the earth thrust, at least for the cases examined by him.

In the figure let ABF represent a retaining wall, backed by earth whose top surface is inclined $\varepsilon°$ to the horizontal. The inner face of the wall $\overline{AB}$ is inclined at an angle α to the vertical, which angle is positive in the figure, but negative if AB lies to the right of the vertical through A.

The thrust E acts at $\frac{1}{3}$ AB, above A, and is inclined to the normal to AB at an angle φ', if $\varphi' < \varphi$, otherwise at an angle φ, as hitherto explained.

Weyrauch gives the following construction for finding the plane of rupture $\overline{AC}$: Draw $\overline{BO}$, making the angle ($\alpha +$

φ') with the normal BN to the natural slope AD, then draw a perpendicular $\overline{OA}$ to intersection, with the semicircle described upon $\overline{AD}$ as a diameter, and lay off $\overline{AI}$ equal to $\overline{AH}$, whence $AI=\sqrt{\overline{AO}.\overline{AD}}$; next draw $\overline{IC}$ parallel to $\overline{BO}$ to intersection c with the top slope, when $\overline{AC}$ will be the plane of rupture. The weight of ABC, for a foot in thickness, will give the value of G in a preceding figure, from which E can be found as there explained. On combining E now with W, the weight of the wall acting through its center of gravity, we find S the resultant on the $\overline{AB}$ to where this line intersects the top slope of earth; γ represents the weight per cubic foot of earth.

For the simple case where the back of wall is vertical and the top slope horizontal, we find the expression,

$$E=\frac{\cos\varphi}{2(1+\sin\varphi\sqrt{2})^2}\cdot h^2\gamma \quad . \quad . \quad (2).$$

in which h represents the height from A, vertically to the top surface of earth filling.

We shall now examine some of the experiments recorded by Mr. Baker, and compare "the actual lateral pressure of

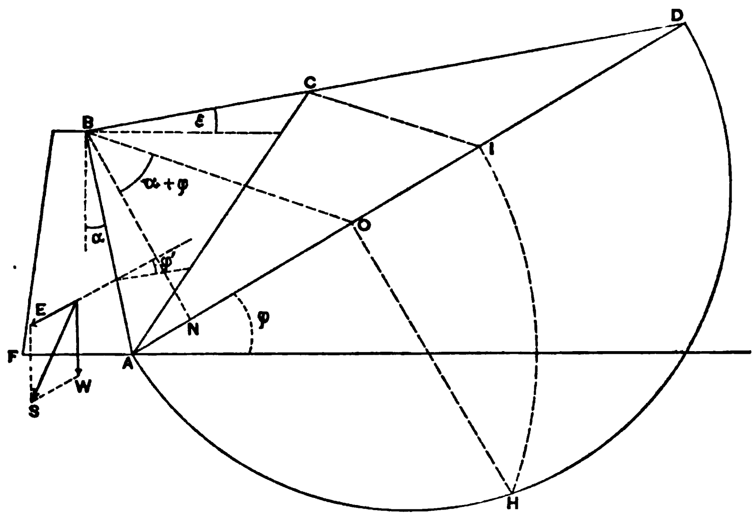


Fig.3

base of the wall; its intersection with $\overline{AF}$ giving the center of pressure on the base.

Instead of the graphical method we may employ the following formulæ for finding the value of the thrust E:

Thus placing

$$\left.\begin{aligned} n&=\sqrt{\frac{\sin(\varphi+\varphi')\sin(\varphi-\varepsilon)}{\cos(\alpha+\varphi')\cos(\alpha-\varepsilon)}} \\ \text{we have}& \\ E&=\left(\frac{\cos(\varphi-\alpha)}{1+n}\right)^2\frac{l^2\gamma}{2\cos(\alpha+\varphi')} \end{aligned}\right\} \quad . \ (1).$$

Bear in mind that when $\varphi'>\varphi$, we must replace φ' in the preceding formulæ by φ. In the formulæ, l represents the inclined height $\overline{AB}$ of the wall, or generally, the distance from A in the direction earthwork" with the theoretical, as given by the above formulæ.

For brevity let us call the

Height of the wall..........	H
Thickness of the wall.......	t
Weight per cubic foot.......	w
Height of the earth.........	h
Weight per cubic foot.......	γ
Angle of repose of earth.....	φ
Ratio of distance from the center of pressure on the base of wall to outer toe, to the thickness t.......	q
Angle of friction of earth on wall...............	φ'

(Ex. 1). A stable wall of pitch-pine blocks, sustaining a bank of Macadam screenings, level at top. H=4, t=1,

$w = 46$, $h = 3.75$, $\gamma = 101$, $\varphi = 39°48'$; whence weight of wall=184 lbs.

φ' is not given, but as Rankine gives the angle of friction of timber on stone as 22°, we can say that it lies between 22° and 39°48′, the latter if the projections of the wooden blocks are sufficient to hold any of the filling.

By eq. (1) for $\varphi'=22°$, we have $n=.824$ and E=136. On combining E, acting at $\frac{1}{3}h$ above the base, with the weight of wall, acting at its center of gravity, we find that the resultant cuts the base at the outer toe $\therefore q=0$.

For $\varphi'=\varphi=39°48'$, we have by eq. (2) E=151, whence by construction $q=0.16$, the resultant striking within the base.

In (Ex. 2), as in some other cases, a surcharged wall is mentioned, but whether any of the surcharge rests on the wall is not stated, so that computation is useless.

In (Exs. 3 and 4) on the direct lateral thrust of sand, on a board one foot square, as in other experiments of this kind by Mr. Baker, the details of the apparatus are not given, so that it is impossible to say how much the results may be modified by the side friction, acting on the wedge of rupture and perhaps on the board.

The same remark applies to (Exs. 5 and 6) giving by experiment the plane of rupture a little nearer the vertical than theory calls for; besides it is doubtful if the surface of rupture is a plane, when friction at the back of the wall is exerted.

(Ex. 7). This is a valuable experiment by Lieut. Hope, on a wall 20 feet long, built of bricks laid in wet sand. We have here h=H=10, $t=1.92$, $w=100$, $\gamma=95.5$, $\varphi=\varphi'=36°53'$. At the moment of falling the overhang was 4 inches. We have weight of wall 1,920, E=1115 whence $q=.05$, the resultant striking outside of the base. If the wall had been regarded as vertical we should find $q=0$.

(Ex. 10). Gen'l Pasley experimented with model retaining walls 3 feet long and 26 inches high, backed up with shingle, by measuring the horizontal force applied at the top necessary to pull them over. Here we have, H=h=2.17, t=0.67, $w=84$, $\gamma=89$, $\varphi=39°$, and the horizontal pull at the top, to cause overturning, 30 lbs. We consequently find weight of wall 364 lbs., E=135 lbs. and $q=\frac{1}{8}$.

In the several hundred experiments the thrust of the shingle varied between very wide limits, "16 and 24 lbs.," 17 being the number used by Mr. Baker.

Such variations only show how careful we should be in condemning any formula that may not agree exactly with a particular case.

Gen'l Burgoyne's experimental walls were each 20 feet long, 20 feet high, and a mean thickness of 3 feet 4 inches. The masonry consisted of "rough granite blocks laid dry, and the filling was of loose earth filled in at random without ramming, or other precautions during a very wet winter."

(Ex. 14). One of the walls was 1′ 4″ at top and 5′ 4″ at bottom, the back being vertical. Assuming $w=142$, $\gamma=112$, $\varphi=33°42'=\varphi'$, we find E=5847, weight of wall 9467; whence $q=0.24$.

The wall was perfectly stable, as the value of q indicates. Of course the wall (Ex. 13) of uniform thickness 3′ 4″ and battered $\frac{1}{2}''$, the height should be stable, judging from the previous case, as more of the material is carried to the rear at the top. Both walls stood easily.

(Ex. 15) describes a wall like (Ex. 14), only turned around, so that the front was vertical. The wall fell by "bursting out" (sliding), at 5′ 6″ from the base and the top descending.

The next wall (Ex. 16) was vertical and fell in the same way, evidently by sliding at about 5 feet above the base, doubtless from the imperfect construction of the rubble work. If the last wall had been a monolithic structure and not moved forward any, the resultant could strike the base $\frac{1}{10}$ diameter inside the base. As it is, it is needless to examine either of the last two experiments for overturning.

(Ex. 17). This wall of Col. Michou's, 40 feet high, with deep *counterforts*, extending back of the face wall 9′ 2″ at top, 2′ 4″ at bottom, 1′ 8″ thick and 5′ from center to center, had a face wall only 1′ 8″ thick, and only fell after the earth was filled in 3 or 4 feet above the top.

"The work was hurriedly constructed during continuous rains with any stones that came to hand, and with very bad lime."

The stability of this wall can only be accounted for in theory, by supposing the

the lateral thrust to cause a binding of the earth between the counterforts, so that this earth may be regarded mostly as a part of the wall. It is really "the most remarkable and interesting" experiment recorded.

This lateral friction, causing a binding of the earth between counterforts close together, certainly adds to the stability of counterforted walls, but how much, experience only can determine. It is on this account that we have not considered other experiments with counterforted walls in a theoretical way.

(Ex. 18). Mr. Constable's experiments on the thrust of peas against wooden bricks, give the following relative data: $H=h=1$, $t=0.4$, $w=1$, $\gamma=2$, $\varphi=27°\ 45'$, whence weight of wall$=4$, and thrust $E=0.32$, thence $q=0.19$, the resultant striking within the base.

"The wall "moved over slightly, but took some amount of jarring to bring it down."

We suspect q is nearer 0.0 than 0.19 for this case, for, as Mr. Baker suggests, a little jarring can easily flatten the slope of repose; besides, the value of φ' is not given, and had to be taken equal to φ, though it is most likely less.

In (Ex. 31), Mr. Baker gives an account of the slightest retaining wall on the underground railway, London, which he finds theoretically unstable, but which is perfectly stable by our theory, the resultant striking the base 0.37 diameter within the base.

The walls previously mentioned have supported new materials placed against them, so that the formulæ should approximately apply, which we find to be the case. But for old ground, thoroughly settled and consolidated by rains, gravity, cohesion, chemical action, &c., it is not pretended that the formulæ apply; it is only experience that can speak here.

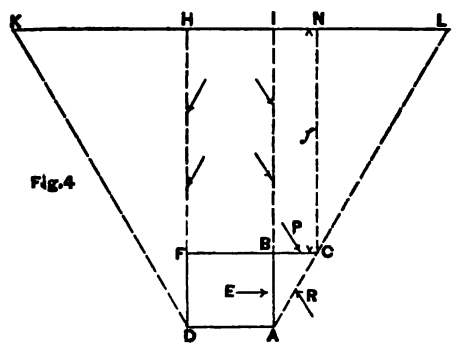
Thus, that the strains on the timbering of the gullets (Exs. 26 and 29) were less than theory calls for, is exactly what we should expect. All such facts should be recorded to give the engineer some data to go by. It is well known that solid clay will stand at a vertical slope for some time, even with a house resting on the very edge of the cutting, as seen in digging foundations for adjacent buildings in towns, but by degrees "the weathering" will cause the clay to assume a gentle slope.

In *shafts* the earth would have to break along the surface of a cone of revolution, and since it cannot move in but slightly, we should not expect such a hollow cone of rupture to press with the same force against the timbering, as the wedge of rupture in the case of the ordinary retaining wall.

In *underground* structures, too, the common theory is inapplicable in part, and must be modified to suit the particular case.

Thus, in the figure, let ABFD represent an underground structure of some kind, box drain, arch culvert, or a

Fig.4



tunnel lining of masonry or timber. If new earth is deposited over the culvert, then it is possible that the whole of the earth HIFB, vertically above the structure, presses on it. But if the culvert settles appreciably, or breaks, then part of the mass of earth above it is upheld by the friction along the sides $\overline{FH}$ and $\overline{BI}$, and its weight is transferred to either side on the principle of the arch.

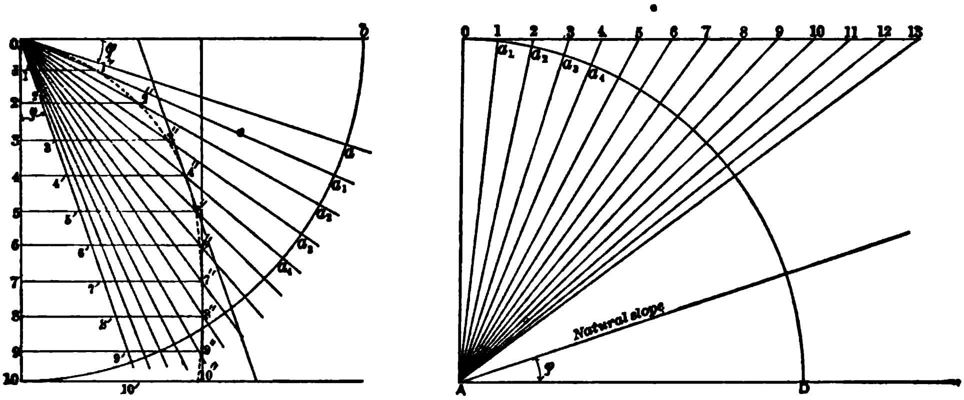
The actions are very complex, but a rough illustration of the principle involved is given in the writer's "*Voussoir Arches, applied to Stone Bridges, Tunnels, &c.*," p. 121. In the case of a tunnel, driven through the ground, a very large part of the weight is transferred to one side, at least at first, before the timbering or masonry is got in. Old compact ground settles very little after the tunnel arch is completed, but in made ground the vertical pressure on the tunnel may increase after construction.

Let us suppose, *in any case*, that the horizontal thrust E, against the planking $\overline{AB}$ is required to be known.

The thrust per square foot, at a depth $x=\overline{NC}$, is given by the usual formula, $= \gamma x \tan^2\left(45^\circ - \frac{\varphi}{2}\right)$, corresponding to the wedge of maximum thrust ABC of indefinitely small dimensions.

But we perceive at once that the wedge ABC cannot slide towards the left without developing friction along $\overline{BC}$, so that the direction of the thrust P on $\overline{BC}$ must not be taken vertical, but inclined at an angle φ to the left of the vertical. As before, R makes the angle φ with the normal to $\overline{AC}$.

Fig. 5



A graphical solution of the case is quickly made.

Thus in the next figure lay off the vertical $\overline{Ao}$=unity, to represent AB. At o draw the horizontal line $\overline{0-13}$, and lay off $\overline{01}$=.1, $\overline{02}$=.2, ... ; then draw the lines A1, A2, . . . , the arc $\overline{oD}$ with centre A, and the line of natural slope, inclined at the angle φ to the horizontal $\overline{AD}$. Next, in the left figure, describe the quadrant with the the same radius $\overline{Ao}$, and lay off below the horizontal $\overline{ob}$ the angle $boa=\varphi$; then the arcs $\overline{aa_1}$, $\overline{aa_2}$, . . . , equal to the corresponding arcs $\overline{oa_1}$, $\overline{oa_2}$, . . . , in the right figure; so that each of the lines $\overline{oa}$, $\overline{oa_1}$, $\overline{oa_2}$, . . . , in the left figure make the angle φ with the normals to the corresponding planes A0, A1, A2, . . . , in the right figure, and thus represents the direction of the resistances R, offered by each plane in turn, regarded as a plane of rupture.

Next, prick off the distances $\overline{01}$, $\overline{02}$, . . . , on the vertical $\overline{0-10}$, equal to the same distances on the line $\overline{0-13}$ in the right figure, and draw the horizontal lines $\overline{11''}$, $\overline{22''}$, . . . , to intersection with the lines $\overline{oa_1}$, $\overline{oa_2}$, . . . , and with the line $0-10'$ draw through o and making the angle φ to the right of the vertical.

Now, as before observed, a certain portion of the weight of earth above the tunnel is transferred to the sides, but its amount cannot be determined; so that we shall take the *vertical component* of the pressure on $\overline{BC}$ (preceding figure) equal to the weight of the prism BCIN of earth directly over it$=\gamma x \times \overline{AB}$, for a prism 1 foot thick in a direction perpendicular to the plane of the paper.

This is evidently the minimum value of this component.

This weight, $\gamma . x . \overline{AB}$, is proportional to $\overline{AB}$, so that regarding $\overline{01}$, $\overline{02}$, . . . , as representing these vertical components, we have only to multiply the horizontal thrust obtained by γx to get the lateral pressure in pounds.

In the left figure the lines 01′, 02′, . . . evidently represent the successive values of P for the wedges of thrust, oA1, oA2, . . ., whence the lines 1′ 11″, 2′ 2″, . . ., represent the corresponding values of the horizontal thrust, and the lines

$\overline{01''}, \overline{02''}$ . . ., the successive values of R; so that for any wedge of thrust $oA4$, the corresponding forces P, E and R, acting on it, are represented by the lines $\overline{04'}$, $\overline{4'4''}$ and $\overline{4''0}$.

By Coulomb's principle, the largest of the values $\overline{1'1''}$, $\overline{2'2''}$, ..., which in this case is $\overline{4'\,4''}=.33$, corresponding to the plane of rupture $\overline{A4}$, is the actual pressure exerted, so that in this case where we have taken $\varphi=18°\ 26'$, on a slope of 3 to 1, we get the lateral pressure per square foot exerted at a depth x,

$$.33\times\gamma.x$$

Here we have neglected the weight of the little wedge ABC, which is thus regarded as indefinitely small in all directions, though we have not drawn it so, since exactly the same construction applies, whether we regard it as large or small, provided we neglect its weight.

The intensity of pressure $0.33\gamma.x$ thus found is only at the depth x, and increases directly with x as we go downward.

Observe that if P is taken vertical that we get $88''.\gamma x=.52\gamma x$ as the lateral thrust per unit, exactly as given by Rankine's formula (the place of rupture is now A8), so that considering the friction exerted along the top of the sliding prism, the horizontal thrust is very much diminished; in fact, for a natural slope of $1\frac{1}{2}$ to 1 this lateral pressure is little more than $\frac{1}{4}$ that is deduced from the common formula. We can now understand why the relative stress found to exist by Mr. Baker (Ex. 25) in the timbering of the roof and sides of the heading of the Campden Hill tunnel, was in the ratio of 3.5 to 1 in place of about 2 to 1 as given ordinarily.

Here the heading was driven at a depth of 44 feet from the surface, and the overlying clay, sand and ballast were heavily charged with water, the slope of repose being 3 to 1, "and the full weight of ground taking effect upon the settings."

The construction above was made for this case, and we found the horizontal thrust per square foot$=.33\gamma x$. The vertical pressure per square foot$=\gamma x$, hence the ratio of the latter to the former is 3 to 1.

We have supposed none of the weight of the material above the tunnel to be transferred to the sides, in which case the ratio would have been larger, as Mr. Baker found.

Having now carefully examined the leading experiments recorded by Mr. Baker, it would seem that we were justified in saying that they agree more nearly with the theory proposed than could have been anticipated, considering the hypothesis on which it is founded.

Cohesion has been neglected altogether, except so far as it is included in taking the angle of frictional repose as equal to that of the same earth endowed with cohesion. There is one experiment recorded though that is inexplicable on any theory, if the pressure was due to weights free to move. Mr. Baker states that he "once applied to a wooden box, full of sand, a pressure equivalent to a column of that material 1,400 feet high before the box burst,"

If the top of the box was free to move as well as the force acting on it, then the wedge of maximum thrust ought to have sheared off and burst the sides of the "little deal box" long before it did.

We shall now continue the investigation by the consideration of such experiments as we happen to have an account of. Mr. Trautwine says (*Engineer's Pocket Book*, p. 333), "that when *not subject to tremor*, a wooden model of a vertical wall, weighing but 28 lbs. per cubic foot and with a base of 35 of its height, balanced perfectly dry sand, sloping at $1\frac{1}{2}$ to 1, and weighing 89 lbs. per cubic foot." He remarks further on: "We cannot understand how correct results are to be expected from experiments like those of Gen. Pasley and others who confined their backing in a box, placing their walls in front of it. The friction of the backing against the sides of the box must diminish the pressure against the wall and thus lead to adopting too slight a thickness.

"We conceive that one experimental wall should diminish in height and thickness each way from its central portion (preserving, however, the same proportion between the two) until it terminates in a point at each end. Ours were made in that way."

These remarks are well put. It may be said though that if the model retaining-wall is long enough, this side friction has less relative effect. Besides, it may be said that in the case of actual walls this side friction must be experienced before the wall gives, though not generally to the same extent as in the experiments quoted.

Mr. Trautwine does not give the angle of friction of his wooden wall on sand, so that we shall have to assume $\varphi'=22°$, as given in the tables. We have here $H=h=1$ when $t=.35$, $w=28$ $\gamma=89$, $\varphi=33° 42$, whence by formula (1) $E=10.9$. The weight of wall is 9.8, and we find $q=.04$ within the base, a very close agreement. The only other experiments we have a record of are given in Curie's *Nouvelle Théorie de la Poussée des Terres*, published in 1870, and *Trois Notes, &c.*, published by the same author in 1873.

These experiments are evidently made with great care, and Curie professes to have upset *l'ancienne théorie*, as he terms the equivalent of the one I am advocating. He takes the thrust causing the greatest moment for *overturning.* This principle would agree with that of Coulomb's maximum thrust, except, perhaps, when the points of application of thrusts corresponding to different wedges were not all at $\frac{1}{3}$ the height as in surcharged walls.

He likewise takes the wedge of rupture that gives the greatest vertical component for the load on the foundation, and the one giving the greatest horizontal component for sliding on the base.

Evidently there is but *one* true thrust, and we think Coulomb's principle establishes it. The same author takes the direction of the thrust against the wall, parallel to the place of rupture, as the particles have a tendency to descend that way, unless this direction makes an angle with the normal to the wall greater than φ' when he squelches the obnoxious component of the "primitive thrust," and makes the little particles of earth next the wall transmit it as best they can to the ground.

Turning to his experiments, we find on page 156 that a vertical wall of wood 0.17 meters high, 0.0485 meters thick and 0.147 meters long, was just at the limit of stability when backed by sand level with the top of the wall, and weighing 1,540 kilograms per cubic meter. The back of the wall was coated with gum covered with sand, as in most of his other experiments, so that $\varphi=\varphi'=35°$. The weight per cubic meter of the wall was 468.5 kilograms. Adapting formula (2) to the French weights and measures, we find

$$E=.1249.\times\overline{17}^2\times1540=5.558 \text{ kilograms.}$$

Weight of wall per meter of length=3.86 kilograms, whence by the usual construction we find that the resultant passes exactly through the outer toe of wall $\therefore q=0$.

On page 137 is described an experiment with a surcharged brick wall in Portland cement (see figure), whose height was 0.9 meter, thickness 0.23 meter, and length 1.014 meters.

The surcharge extended over the entire top of the wall at a slope of 45°, the natural slope of the sand, to a height of 1.30 meters above the top. The angle of friction of the wall on the sand was $\varphi'=35°$, and the weight per cubic meter of the sand was $\gamma=1260$ kilograms, that of the wall $w=2024$ kilograms. The wall fell when the surcharge was carried to the height indicated.

Having drawn the lines $\overline{A1}$, $\overline{A2}$, $\overline{A3}$,..., to indicate supposable planes of rupture, it is a convenience to reduce the areas of A01, A02, A023, . . . , to that of the triangles A01′, A02′, A03′, . . . , so that the weight of any assumed wedge of rupture, as A024, is equal to $\frac{\overline{A0}\times\overline{04'}}{2}\times\gamma$. We effect this by the common geometrical device of drawing $\overline{11'}\|\overline{A0}$, $\overline{22'}\|\overline{A0}$, $\overline{33''}\|\overline{A2}$ and $\overline{3''3'}\|\overline{A0}$, etc., thus reducing each successive triangle to an equivalent one having the same base and altitude.

Next lay off on the vertical $\overline{06}$ of the force diagram on the left the distances $\overline{01}$, $\overline{02}$, $\overline{03}$, . . . , equal to the corresponding distances $\overline{01'}$, $\overline{02'}$, $\overline{03'}$, . . . , in the right figure, and draw through the points 1, 2, 3, . . . , the lines $\overline{11'}$, $\overline{22'}$, . . . , inclined at an angle of $\varphi'=35°$ to the horizontal, to intersection with the lines through o, inclined at an angle φ to the normal to the successive planes of rupture $\overline{A1}$, $\overline{A2}$, . . . , drawn as before explained.

For any supposable prism of rupture then as A024, its weight, the thrust against the wall and that against the plane A4 are in the ratio of the sides of the corresponding triangle in the force diagram 044′, whose sides are parallel to the direction of these forces. We find the prism corresponding to the greatest thrust to be A024 and the corresponding thrust $=44'$ (in left Fig.) $\times\frac{A0}{2}\times\gamma=.41\times\frac{1.13}{2}\times1260=291.8$ kilograms.

The weight of wall and earth over it is equal to 452 kilograms. On combining this weight, acting at the common center of gravity, with the earth thrust acting at $\frac{1}{3}$A0 above A we find that the resultant passes through the outer toe of wall $\therefore q=0$. It is not exact to take the earth thrust as acting at $\frac{1}{3}\overline{A0}$ above A, since A024 is not a triangle, so that the earth thrust does not increase uniformly as we go down from the point 0; still in this particular instance the error is very small since A024 does not differ greatly from the triangle A04′.

When the surcharge is slight, as in the next Figure, it is a nearer approximation to suppose the earth filled in at cD1, $\overline{cD}$ being drawn parallel to AN the plane of rupture.

The successive planes of rupture, corresponding to different depths below c are now all parallel, so that the earth thrust increases uniformly as we go down and will be proportional to the ordinates parallel to $\overline{AN}$ of the trapezoid $\overline{cDNA}$.

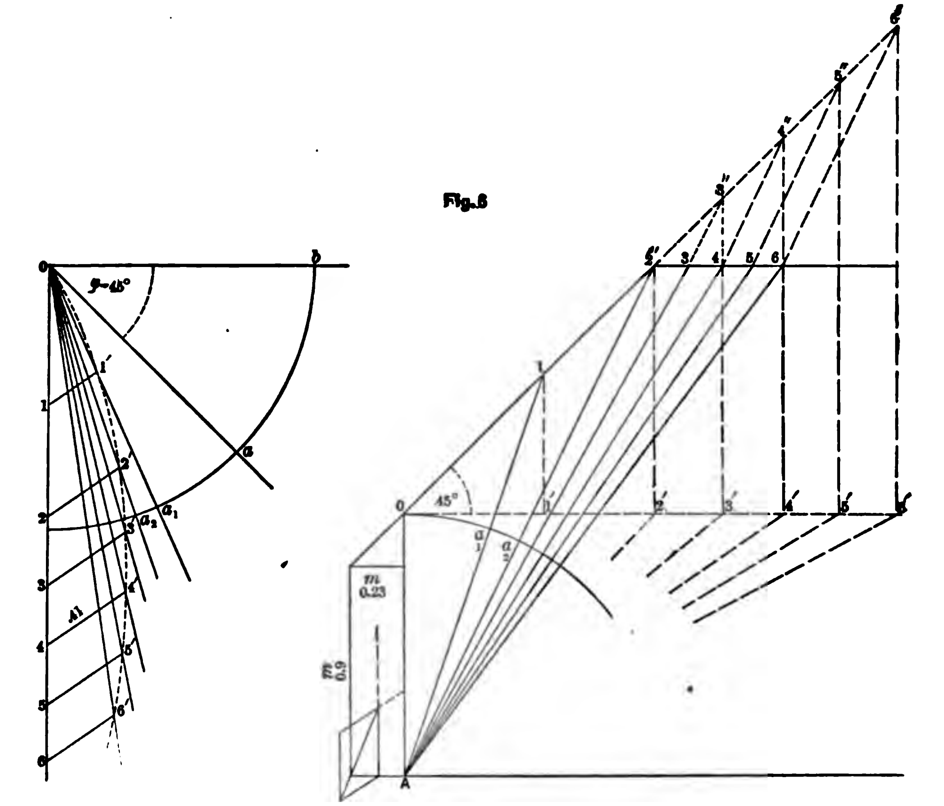


Fig. 6

The earth thrust will therefore be applied at a depth below B equal to

$$\frac{2}{3}\,\frac{\overline{BA}^3-\overline{BC}^3}{\overline{BA}^2-\overline{BC}^2}$$

This is evidently a little above its true position. When the surcharge has intermediate positions the center of pressure on the plane $\overline{Ac}$, will lie between the two positions indicated. Recurring again to the experiments, we find one in the *Trois Notes*, p. 11, represented by the adjoining Figure. Here the frame IBA, weighing 53^k, supported the dry sand filling BAc, weighing 1555^k per cubic meter. The length $\overline{AB}$ was one meter, $\overline{AB}$ being the section of a board, one meter square, against which the sand rested. The center of gravity g was determined by experiment.

The angle BAD=27°30 and $\varphi=\varphi'=33°30'$, M. Curie finds that "the old theory" would require a base $\overline{AI}=0.^m395$ for stability, whereas his theory calls for $\overline{AI}=0.^m462$. With the latter base it required an "effort of two fingers of each hand to overturn" the frame backed by the sand.

"In consequence of atmospheric humidity (28 Feb. 1873) the sand had retaken a slope of 35°", and "the overturning was spontaneous though very slow" when the chord AI was 0.450 meters.

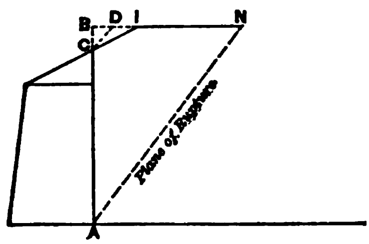


Fig.7

The angle BAD corresponds now to the angle the plane of rupture Ac makes with the vertical $\therefore$ $BAD=DAC=45°-\frac{\varphi}{2}=27°\ 30'$.

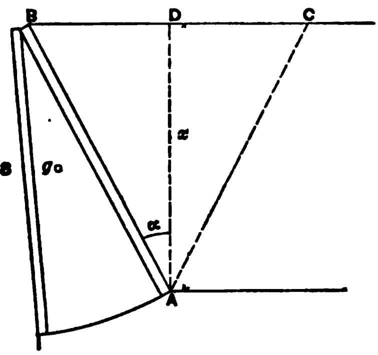
The thrust on plane AD by Rankine's method is horizontal and equal to 165.4; on combining this with the weight of BAD=318.9, we get the thrust on plane $\overline{AB}$ the same we should find it on plane $\overline{AC}$, so that this thrust is inclined at the angle φ to the normal to $\overline{AB}$; hence in this case the two theories agree. On combining this thrust with the weight of the revetment, we find that the resultant intersects the base $^m.066$ or .15 chord AI from the point I, a rather larger difference than we have found hitherto for these carefully-made experiments.

In the next experiment the angle BAD was 55° the chord AI, $0^m.545$, and $\varphi=\varphi'=33°30'$.

M. Curie finds that his theory gives $AI=0^m.565$, very near the actual, whereas "l'ancienne théorie" gives $AI=0^m.423$, a flagrant "désaccord" to which he triumphantly points.

Let us examine this particular application of the ancient theory a little, for in this case if φ was 35°, *the thrust inclined at this angle to* AB, which is itself inclined 55° away from the vertical, would be absolutely vertical, *i.e.*, there would be no horizontal component of the thrust caused by the wedge of rupture BAc, which is evidently absurd. The truth is, the ancient theory no longer applies after passing the plane $\overline{AB}$ inclined at an angle $\left(45-\frac{\varphi}{2}\right)$ with the vertical. We shall prove this by the aid of Rankine's

Fig.8



sole principle used in constructing his elegant theory of earth pressure: "*It is necessary to the stability of a granular mass, that the direction of the pressure between the portions into which it is divided by any plane should not, at any point, make with the normal to that plane an angle exceeding the angle of repose.*" Now the old theory, which assumes the direction of the thrust on the wall to make an angle with the normal to the wall equal to φ, would cause the thrust on the plane $\overline{AB}$, inclined at an angle $\left(45-\frac{\varphi}{2}\right)$, with the vertical, to make an angle with the normal to that plane greater than φ, contrary to the principle enunciated.

Let AD=x, and angle BAD=a.

By the usual formula, if the thrust on AD is taken horizontal its value is

$$H=\tfrac{1}{2}\gamma x^2 \tan^2\left(45-\frac{\varphi}{2}\right).$$

The weight of the wedge ABD is

$$W=\tfrac{1}{2}\gamma x^2 \tan a.$$

On combining H with W, we get the true thrust on $\overline{AB}$ when $a>45-\frac{\varphi}{2}$, as we shall show. Let us call d the angle that the thrust on the plane $\overline{AB}$ makes with the normal to that plane:

$$\therefore \tan(a+d)=\frac{W}{H}=\frac{\tan a}{\tan^2\left(45-\frac{\varphi}{2}\right)}.$$

It may be proved that when

$$a>45-\frac{\varphi}{2},\ \textit{that}\ d<\varphi$$

We have only to verify the inequality

$$\tan(a+\varphi)>\tan(a+d)$$

$$\therefore \frac{\tan(a+\varphi)}{\tan a}>\tan^2\left(45+\frac{\varphi}{2}\right)$$

If the angle,

$$a=\left(45-\frac{\varphi}{2}\right)+\beta,$$

this becomes,

$$\frac{\tan\left(45+\frac{\varphi}{2}+\beta\right)}{\tan\left(45-\frac{\varphi}{2}+\beta\right)}>\tan^2\left(45^\circ+\frac{\varphi}{2}\right)$$

or

$$\tan\left\{\left(45+\frac{\varphi}{2}\right)+\beta\right\}\tan\left\{\left(45+\frac{\varphi}{2}\right)-\beta\right\}>\tan^2\left(45+\frac{\varphi}{2}\right)$$

For brevity placing $\left(45+\frac{\varphi}{2}\right)=x$, we reduce, by the usual formulæ for the tangent of the sum and difference of two angles, the above in equality to

$$\frac{\tan^2 x-\tan^2\beta}{1-\tan^2 x\tan^2\beta}>\tan^2 x$$

Clearing of fractions and transposing, we deduce

$$\tan^4 x>1\ \therefore \tan^4\left(45+\frac{\varphi}{2}\right)>1$$

which we know to be true for the values of φ in question.

Now suppose, in accordance with the old theory, we had assumed $d=\varphi$, as usual. Starting with the deduced resistance of the wall we work back, combining it with the wedge of earth lying below the plane inclined $\left(45-\frac{\varphi}{2}\right)$ to the vertical, to get the thrust on that plane, which is thus inclined at a greater angle than φ to its normal; for we have just found that when this inclination was φ that $d<\varphi$, consequently the assump- $d=\varphi$ requires the horizontal component of the thrust to be diminished, which thus causes the thrust on the plane inclined $\left(45-\frac{\varphi}{2}\right)$ to the vertical to make a greater angle than φ with its normal, which is contrary to Rankine's principle.

The resultant of H and W then gives the thrust on the plane AB when a is equal to or greater than $\left(45-\frac{\varphi}{2}\right)$, and the wall in overturning will carry with it a part of the earth, as there is a greater tendency of the earth to slide along the plane inclined $\left(45-\frac{\varphi}{2}\right)$ to the vertical, than below that plane.

Making use now of the revised theory we find in the last example where $a=55^\circ$ that $H=73.86^k$, $W=365.42^k$, which combined with each other and then with the weight of wall 53^k, gives a resultant which strikes the base $^m.009$ or only .017 diameter of base from the very edge.

We have one more experiment to record similar to the last one. In this case (see Curie p. 150) $\overline{AB}=.2$ meter, $\overline{AB}$ representing a square board as before, $a=55^\circ$, $\varphi=\varphi'=35^\circ$ $\gamma=1450$, $w=2.27$, $A1=^m.101$.

We find

$$H=2.59$$
$$W=13.67$$

whence by construction, the final resultant is found to pass only $^m.0065$ or .06 of the chord of the base from the outer toe of the framed revetment.

We shall now give in a little table a condensed summary of our results pertaining to retaining walls *at the limit of stability.*

Authority.	H	t	w	h	γ	φ	φ'	q	Remarks.
	feet.	feet.	lbs.	feet.	lbs.				
Lieut. Hope.	10.	1.92	100	10	95.5	36°53′	36°53′	+.05	Earth level at top.
Gen. Pasley.	2.17	.67	84	2.17	89	39°	39 (?)	−.12	" " "
C. Constable.	1.	.4	1	1	2	27°45′	27°45′ (?)	−.19	" " " ratios given.
Trautwine..	1	85	28	1	89	33°42′	22° (?)	+.04	" "
	meters.	meters.	kilog.	meters.	kilog.				
Curie.......	.17	.0485	468.5	.17	1540	35°	85°	.00	Level-topped earth.
"	.90	.23	2024.	2.2	1260	45°	85	.00	Surcharge 1m.8 above top of wall.
"	.1148	.114	2.27	1148	1450	35°	35°	−.06	Earth level.
"	.887	.450	53.	.887	1555	35°	35°	−.15	" "
"	.5736	.545	53.	.574	1555	33°30′	33°30′	−.02	" "

Average q—.05.

All the walls were vertical rectangular walls, except the last three which were very light frames of triangular cross section.

The experiments are not of equal value for reasons given, though we have averaged the values of q on that supposition. This average shows that the corresponding resultant passes only five per cent. of the diameter from the outer toe of the base and inside of the same, as the minus sign is meant to indicate. As far as the experiments go, they seem to give faith in the theory as a working theory; still they have generally been made on a small scale and much side friction has probably been developed, except in the case of Trautwine's model, which, singularly enough, agrees in the results with the other experiments.

It will be very beneficial to the profession, if engineers will contribute their knowledge on this subject, and compare the results of their experience with theoretical formulas, so that a good working formula may at last be decided upon.

The experiments have certainly established the fact that the friction at the back of the wall between it and the earth promotes the stability of the wall to a large degree, though it is not improbable that, in some cases, this friction may be lessened or destroyed in walls of large stability, with well settled sand or gravel backing, so that the full thrust, the maximum, as given by Rankine, may be felt.

Certainly it seems that we are justified in saying, that as a rule for *new materials* the actual thrust cannot exceed that given by Rankine, nor generally fall below that found when the whole wall friction is included; so that if we design a wall that is theoretically safe against overturning and sliding on both suppositions, its stability is practically assured.

The wall will not overturn until the whole of the friction at the back of the wall is developed, according to the experiments; so that if we adopt the European plan of taking the thrust E as double that given by formulæ (1) or (2) in *designing* a wall, its stability is assured, at least. It is said for good foundations that the results agree with those of Vauban, whose retaining walls have stood the test of time, though failures have been recorded in this country for some walls designed by such a formula.

It would seem more scientific and satisfactory every way, to require that the resultant of the thrust as given by formulæ (1) or (2), should pass a certain proportion of the base from the outer toe. If this proportion is assured = $\frac{1}{3}$, then there will be only compressive stress exerted at the base, which it seems to me desirable, especially when the mortar is green, as it prevents any joints opening at the back of the wall. The resultant could pass much nearer the outer toe, so far as crushing of the material there is to be guarded against.

Let us see what this requirement will lead to.

Thus take a vertical rectangular wall 10 feet high, backed by earth level with the top, whose angle of repose is φ = 33°42, corresponding to the slope of $1\frac{1}{2}$ to 1. The thrust is, when γ is taken equal to unity,

$$E = \frac{100}{2} \frac{\cos \varphi}{(1+\sin \varphi \sqrt{2})^2} = 13.1$$

the relative weight of wall is $10 \times 3\frac{1}{3} \frac{w}{\gamma}$.

Now a construction on a large scale will show that in order that the resultant on the base strikes it one-third of its diameter back from the outer edge, that this ratio $\frac{w}{\gamma}$ of specific weights of masonry and earth should equal 1.095; or practically the weight per cubic foot of the masonry should be one and one-tenth times that of the earth—a perfectly *safe* proportion, as a rule.

The proportion of $\frac{1}{3}$ for height to base is what Mr. Baker gives as the result of his own extensive experience; and he says further, that "it has been similarly proved by experiment, that under no ordinary conditions of *surcharge* or *heavy backing*, is it necessary to make a retaining wall on a solid foundation, more than $\frac{1}{2}$ the height in thickness."

Let us examine this limit theoretically, by considering a vertical rectangular wall, 10 feet high and 5 feet thick *surcharged* entirely over the top with earth, sloping indefinitely at the angle of repose $1\frac{1}{2}$ to 1, the most unfavorable conditions for stability.

We have here $\varepsilon = \varphi$, and the formula we have been using reduces to that given by Rankine,

$$E = \frac{h^2}{2} \cos 33°42'.$$

Successive trials showed us that for $\frac{w}{\gamma} = 1.1$, and in order that the resultant on the base pass exactly $\frac{1}{3}$ diameter of the base from the outer toe that the thickness of the wall should be a little more than .8 of its height; so that for a wall 10 feet high and 8 feet thick, *entirely* covered with the surcharge, the value of h in the formula above equals 15.33, whence $E = 97.76$, and acts at 5.11 feet above the base, and the weight of wall $8 \times 10 \times 1.1 = 88$.

A construction will now show the facts above stated, and further, that the resultant on the base is inclined 30° to the vertical, so that the wall must slide if resting on clay (angle of friction with dry clay is 27°) unless the earth in front of it can resist it, or the foundation courses are made more inclined to the horizontal. This result does not agree at all with the thickness given as the limit by Mr. Baker. There is a choice to be made evidently, and as one experiment of Curie's on a surcharged wall exactly sustained the theory, it seems that we must seek elsewhere for the discrepancy.

Is it not that constructors do not use the same factor of safety for walls with high surcharges as for walls with earth level with their top?

Or is not the retaining wall, as built, at last a compromise between the two theories, which differ considerably for level-topped earth, and gradually approach each other as the top slope nears the angle of repose?

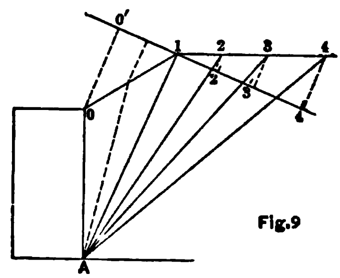


Fig. 9

If the latter, then it seems useless to frame a table on either theory to work by, except as indicating reasonable limits.

We give below some approximately correct tables, that are made out on the supposition that the specific gravity of the masonry is 1.1 times that of the earth (*safe* for brick walls backed by sand or rock walls with the heaviest earth filling), and that the resultant on the base passes $\frac{1}{3}$ of its diameter from the outer toe, using the theory which includes the whole of the friction at the back of wall.

In the first table the surcharge is supposed to extend from *o* backwards, at the natural slope ($1\frac{1}{2}$ to 1), until the level plane $\overline{14}$ is attained.

The figure shows the neatest way of laying off the equivalent triangles having the same base $\overline{A1}$, by drawing parallels to $\overline{A1}$ through 0, 2, 3, 4, . . to intersection with the perpendicular to $\overline{A1}$ through

1. Thus the area of A014A is replaced by A0'4'A; so that by using the distances 0'1, 0'2', . . . , on the force diagram, to represent the weight of the earth prisms, we have simply to multiply the value of E, given by construction, by $\frac{1}{2}$ of $\overline{A1} \times \gamma$.

The plane of rupture will always be found to the right of $\overline{A1}$, so that it is needless to draw any planes to the left.

The first column in the table (h') gives the ratio of the height of the top of the surcharge above the top of the wall to the height of the wall; the next, the thickness of the wall (t) for height 1; and the third column (i), the inclination of the resultant on the base (which passes $\frac{1}{3}$ diameter from outer edge) to the vertical.

Those quantities marked with a star were found by actual trial, the balance interpolated.

SURCHARGE COMMENCING AT BACK OF WALL.

h'	t	$i°$	h'	t	$i°$
0	.38*	14°	.4	.44	
.1	.38		.5	.45*	18°
.2	.41		.7	.46	
.25	.42*	15°	1.0	.48	
.3	.43		∞	.48*	24°

The next table is very roughly interpolated from four actual cases marked with a star.

The surcharge now extends over the entire top of the wall at the slope of $1\frac{1}{2}$ to 1, the angle of repose assumed, until it meets the level plane.

As before, $\frac{w}{\gamma} = 1.1$, $\varphi = \varphi' = 33°42'$, $q = \frac{1}{3}$.

SURCHARGE EXTENDING OVER TOP OF WALL.

h'	t	$i°$	h'	t	$i°$
.0	.38*	14°	.8	.69*	20°
.2	.44		1.	.74	
.4	.58*	17°	1.5	.80	
.6	.62		∞	.82*	30°

The earth resting on the top of the wall was not considered, though it does help by its weight to a small extent.

Especial attention is called here to the large inclinations to the vertical of the resultant on the base.

A number of the walls would not stand on dry clay, and with wet clay whose angle of friction with masonry is only $18\frac{1}{4}°$, how many of the walls would slide as soon as the foundation was saturated with water?

It seems folly not to incline the joints of the lower courses of a retaining wall to obviate this sliding, which is really more to be feared in the majority of cases of actual walls than overturning. This is especially true of dock walls, though it seems to have been least of all considered in construction, if we are to judge from the numerous sections of actual structures given by Mr. Baker.

Turning now to Mr. Trautwine's "Engineer's Pocket Book," p. 334, we find a table of thicknesses of retaining walls for various surcharges, as deduced from some rough experiments with wooden walls and sand backing.

For the vertical rectangular wall, with earth level at top, he gives the thickness, .35 the height; but for a surcharge of indefinite slope starting at the back of the wall as much as .68 the height, in place of the .48 found above. This is probably due to the fact that he did not coat the back of his retaining walls with sand, thus causing the earth thrust to take a more nearly horizontal direction.

We have seen in the case of the experiment of Curie's, of a brick wall, coated with Portland cement and having a high surcharge, that $\varphi' = 35°$ whilst φ was 45°.

The theory exactly applied here, taking the thrust as inclined at the angle $\varphi' = 35°$ with the horizontal, though it would have indicated quite a stable wall if φ' had been assumed equal to $\varphi = 45°$.

The table quoted by Trautwine from Poncelet is sensibly erroneous for high surcharges, as Scheffler has shown, owing to the approximations introduced by Poncelet in his formulæ, and especially the error of taking the thrust as horizontal against the wall.

Any of the dimensions given can be tested by computation, or by the *graphical* construction already illustrated, a method that will put the average reader in full possession of the means to test the stability, in a sufficiently precise manner, of any kind of retaining wall, sustaining any character or shape of backing; and besides has the advantage of keeping before the eyes of the investigator the hypotheses upon which his theory is founded, so that the theory may not be applied erroneously.

NOTES ON THE BEST METHOD OF MEETING THE SANITARY REQUIREMETS OF COLONIAL TOWNS.

By EDWARD DOBSON, M. Inst. C.E.

From Abstracts of Institution of Civil Engineers.

The author's remarks are applicable to new towns, as distinguished from closely built towns in the old World.

In planning new towns favorable conditions may be secured by legislative enactment, which are unattainable where the ground has been closely built upon without regard to sanitary requirements.

Each dwelling should have a supply of water of not less than 20 gallons per day per inmate, exclusive of the quantity required for flushing closets. If rain water is to be stored the tanks should be covered so as to exclude the sun's rays, the light and heat of which have a powerful effect in promoting vegetable growth. Every dwelling should have a properly constructed receptacle for ashes and kitchen refuse. Sunk cesspools for excreta should be strictly prohibited within the boundary of every township. Ash-middens may be adopted, that is a privy and ash-heap may be combined, if the floor be paved and slightly raised above the general surface of the ground, and a drain be laid to carry off any liquid not absorbed by the ashes; or movable pans or pails may be adopted, if fitted with air-tight lids for use during removal, and disinfected before they are replaced. But in all cases, whether of receptacles for refuse, ash-middens, or movable pans, they should be compulsorily emptied at short intervals under municipal regulations.

Water closets may be adopted, under certain circumstances, but their introduction involves a considerable amount of municipal organization, for the double purpose of providing a water supply for flushing them and a system of underground drains for the removal of the excreta; whereas, if either of the other systems be adopted, it is only the house slops which require to be drained away, and they may be drained into the street gutters if these be kept constantly flushed by an efficient water supply. The author does not approve of water closets in new towns, inasmuch as the drains in connection with them disseminate infectious disease, and he asks whether it is not a solemn duty to resist the introduction of an evil which conduces to the lowering of the physical standard of the future population.

In almost every district there will be found channels by which the water of heavy rainfalls passes off to lower levels. Instead of blocking up these natural channels, as is too often done in the formation of streets, they should be utilized, straightened, deepened and connected with suitable outfalls to the river. When the lines of drainage have been marked out the storm water channels reserved, and the position and levels of the outfalls defined, and not before, the streets of the town may be laid out, taking care in doing so to grade the streets in such manner that the surface water on every property may drain into the street gutters, and these into the outfall. In a new country the work of the engineer should precede, and not follow, that of the settlement surveyor; and until this principle is recognized, and acted upon by colonial governments, the history of colonial progress will always be a record of costly struggles to regain facilities of communication, drainage and water supply, which have been heedlessly sacrificed by handing over the Crown lands to private ownership, without due reservation of conditions essential to the general welfare of the community.

SOME OF THE DEVELOPMENTS OF MECHANICAL ENGINEERING DURING THE LAST HALF CENTURY.

By SIR FREDERICK BRAMWELL, V.P. Inst. C E., F.R.S.

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I AM quite sure the section will agree with me in thinking, it was very fortunate for us, and for science generally, that our President refrained from occupying the time of the section by a retrospect, and devoted himself, in that lucid and clear address with which he favored us, to the consideration of certain scientific matters connected with engineering, and to the foreshadowing of the directions in which he believes it possible that further improvements may be sought for. But I think it is desirable that some one should give to this section a record, even although it must be but a brief and imperfect one, of certain of the improvements that have been made, and of some of the progress that has taken place, during the last fifty years, in the practical application of mechanical science, with which science and its applications our section is particularly connected. I regret to say that, like most of the gentlemen who sat on this platform yesterday, who, I think, were, without exception, past presidents of the section. I am old enough to give this record from personal experience. Fifty years ago I had not the honor of being a member, nor should I, it is true, have been eligible for membership of the Association; but I was at that time vigorously making models of steam-engines, to the great annoyance of the household in which I lived, and was looking forward to the day when I should be old enough to be apprenticed to an engineer. Without further preface, I will briefly allude to some of the principal developments of a few of the branches of engineering. I am well aware that many branches will be left unnoticed; but I trust that the omissions I may make will be remedied by those present who may speak upon the subject after me.

I will begin by alluding to the *steam-engine employed for manufacturing purposes.* In 1831, the steam-engine for these purposes was commonly the condensing beam engine, and was supplied with steam from boilers, known, from their shape, as wagon boilers; this shape appears to have been chosen rather for the convenience of the sweeps, who periodically went through the flues to remove the soot consequent on the imperfect combustion, than for the purpose of withstanding any internal pressure of steam. The necessary consequence was, that the manufacturing engines of those days were compelled to work with steam of from only 3½ lbs. to 5 lbs. per square inch of pressure above atmosphere. The piston speed rarely exceeded 250 feet per minute, and as a result of the feeble pressure, and of the low rate of speed, very large cylinders indeed were needed relatively to the power obtained. The consumption of fuel was heavy, being commonly from 7 lbs. to 10 lbs. per gross indicated horse power per hour. The governing of the engine was done by pendulum governors, revolving slowly, and not calculated to exert any greater effort than that of raising the balls at the end of the pendulum arms, thus being, as will be readily seen, very inefficient regulators. The connection of the parts of the engine between themselves was derived from the foundation upon which the engine was supported. Incident to the low piston speed, was slowness of revolution, rendering necessary heavy fly-wheels, to obtain even an approach to practical uniformity of rotation, and frequently rendering necessary also heavy trains of toothed graining, to bring up the speed from that of the revolutions of the engine to that of the machinery it was intended to drive.

In 1881, the boilers are almost invariably cylindrical, and are very commonly internally fired, either by one flue or by two; we owe it to the late Sir William Fairbairn, President of the British Association in 1861, that the danger, which at one time existed, of the collapse of these fire flues, has been entirely removed by his application of circumferential bands. Now-a-days there are, as we know, modifications of Sir William Fairbairn's bands, but by means of his bands, or by modifications thereof, all internally flued boilers are so strengthened that the risk of a collapse of the flue is at an end. Boilers of this kind are well calculated to furnish—and commonly do furnish—steam of from 40 lbs. to 80 lbs. pressure above atmosphere. The piston speed is now very generally 400 feet or more, so that, notwithstanding that there is usually a liberal expansion, the mean pressure upon the piston is increased, and this, coupled with its increased speed, enables much more power to be obtained from a given size of cylinder than was formerly obtainable. The revolutions of the engine now are as many as from 60 to 200 per minute, and thus, with far lighter fly-wheels, uniformity of rotation is much more nearly attained. Moreover, all the parts of the engine are self-contained; they no longer depend upon the foundation, and in many cases the condensing is effected either by surface condensers, or, where there is not sufficient water, the condensation is, in a few instances, effected by the evaporative condenser—a condenser which, I am sorry to say, is not generally known, and is therefore but seldom used, although its existence has been nearly as long as that of the Association. Notwithstanding the length of time during which the evaporative condenser has been known to some engineers, it is a common thing to hear persons say, when you ask them if they are using a condensing engine, "I cannot use it; I have not water enough." A very sufficient answer indeed, if an injection condenser, or an ordinary surface condenser, constituted the sole means by which a vacuous condition might be obtained; but a very insufficient answer, having regard to the existence of the evaporative condenser, as by its means, whenever there is water enough for the feed of a non-condensing engine, there is enough to condense, and to produce a good vacuum. The evaporative condenser simply consists of a series of pipes, in which is the steam to be condensed, and over which the water is allowed to fall in a continuous rain. By this arrangement there is evaporated from the outside of the condenser a weight of water which goes away in a cloud of vapor, and is nearly equal to that which is condensed, and is returned as feed into the boiler. The same water is pumped up and used outside the condenser, over and over, needing no more to supply the waste than would be needed as feed water. Although this condenser has, as I have said, been in use for thirty or forty years, one still sees engines working without condensation at all, or with water-works water, purchased at a great cost, and to the detriment of other consumers, who want it for ordinary domestic purposes; or one sees large condensing ponds made, in which the injection water is stored, to be used over and over again, and frequently (especially towards the end of the week) in so tepid a state as to be unfit for its purpose. The governing is now done by means of quick-running governors, which have power enough in them to raise not merely the weight of the pendulum ball, which is now small, but a very heavy weight, and in this way the governing is extremely effective. I propose to say no more, looking at the magnitude of the whole of my subject, upon the engine used for manufacturing purposes, but rather to turn at once to those employed for other objects.

Steam navigation.—In 1831, there was a considerable number of paddle steamers running along some of the rivers in England, and across the Channel to the Continent. But there were no ocean steamers, properly so-called, and there were no steamers used for warlike purposes. As in the case of the wagon boilers, the boilers of the paddle steamers of 1831 were most unsuited for resisting pressure. They were mere tanks, and there was as much pressure when there was no steam in the boiler from the weight of the water on the bottom, as there was at the top of the boiler from the steam pressure when the steam was up. Under these circumstances again, from 3½ lbs. to 5 lbs. was all the pressure the boilers were competent to bear, and as the engines ran at a slow speed, they developed but a small amount of horse-power in relation to their size. Moreover, as in the land engine, the connection between the parts of the marine engine was such as to be incompetent to stand the strain that would come upon it if a higher pressure, with a considerable expansion, were used, and thus the consumption of coal was very heavy; and we know, that having regard to the then consumption, it was said on high authority, it would be impossible for a steamboat to traverse the Atlantic, as it could not carry fuel enough to take it across; and indeed it was not until 1838 that the Sirius and Great Western did make the passage. The passage had been made before, but it was not until 1838 that the passenger service can be said to have commenced. In 1831, the marine boiler was supplied with salt water, the hulls were invariably of wood, and the speed was probably from eight to nine knots an hour. In 1881, the vessels are as invariably either of iron or of steel, and I believe it will not be very long before the iron disappears, giving place entirely to the last-mentioned metal. With respect to the term "steel," I am ready to agree that it is impossible to say where, chemically speaking, iron ends and steel begins. But (leaving out malleable cast iron) I apply this term "steel" to any malleable ductile metal of which iron forms the principal element, and which has been in fusion, and I do so in contradistinction to the metal which may be similar chemically, but which has been prepared by the puddling process. Applying the term steel in that sense, I believe, as I have said, it will not be very long before plate iron produced by the puddling process will cease to be used for the purpose of building vessels. With respect to marine engines, they are now supplied with steam from multiple-tubed boilers, the shells of which are commonly cylindrical. They are of enormous strength, and made with every possible care, and carry from 80 lbs. to 100 lbs. pressure on the square inch. It has been found, on the whole, more convenient to expand the steam in two or more cylinders, rather than in one. I quite agree that, as a mere matter of engineering science, there is no reason why the expansion should not take place in a single cylinder, unless it be that a single cylinder is cooled down to an extent which cannot be overcome by jacketing, and which, therefore, destroys a portion of the steam on its entering into the cylinder. As regards the propeller, as we know, except in certain cases, the paddle wheel has practically disappeared, and the screw propeller is all but universally employed. The substitution of the screw propeller for the paddle enables the engine to work at a much higher number of revolutions per minute, and thus a very great piston speed, some 600 ft. to 800 ft. per minute is attained; and this, coupled with the fairly high mean pressure which prevails, enables a large power to be got from a comparatively small-sized engine. Speed of fifteen knots an hour are now in many cases maintained, and on trial trips are not uncommonly exceeded. Steam vessels are now the accepted vessel of war. We have them in an armored state, and in an unarmored state, but when unarmored rendered so formidable, by the command which their speed gives them of choosing their distance, as to make them, when furnished with powerful guns, dangerous opponents even to the best armored vessels. We have also now marine engines, governed by governors of such extreme sensitiveness as to give them the semblance of being endowed with the spirit of prophecy, as they appear rather to be regulating the engine for that which is about to take place than for that which is taking place. This may sound a somewhat extravagant statement, but it is so nearly the truth, that I have hardly gone outside of it in using the words I have employed. For a marine governor to be of any use, it must not wait until the stern of the vessel is out of the water before it acts to check the engine and reduce the speed. Nothing but the most sensitive and, indeed, anticipatory action of the governors can efficiently control marine propulsion. Instances are on record of vessels having engines without marine governors being detained by stress of weather at the mouth of the Thames, while vessels having such governors, of good design, have gone to Newcastle, have come back, and have found the other vessels still waiting for more favorable weather, With respect to the condensation in marine engines, it is almost invariably effected by surface condensers, and thus it is that the boilers, instead of being fed with salt water as they used to be, involving continuous blowing off, and frequently the salting up of the boiler, are now fed with distilled water. It should be noticed, however, that in some instances, owing to the absence of a thin protecting scale upon the tubes and plates, very considerable corrosion has taken place when distilled water, derived from condensers having untinned brass tubes, has been used, and where the water has carried into the boiler fatty acids, arising from the decomposition of the grease used in the engine; but means are now employed by which these effects are counteracted.

I wish, before quitting this section of my subject, to call your attention to two very interesting, but very different, kinds of marine engines. One is the high speed torpedo vessel, or steam launch, of which Messrs. Thornycroft's firm have furnished so many examples. In these, owing to the rate at which the piston runs to the initial pressure of 120 lbs., nnd to very great skill in the design, Messrs. Thornycroft have succeeded in obtaining a gross indicated horse power for as small a weight as half a cwt., including the boiler, the water in the boiler, the engine, the propeller shaft and the propeller itself.

To obtain the needed steam from the small and light boiler, recourse has to be made to the aid of a fan blast driven into the stokehole. From the use of a blast in this way advantages accrue. One is, as already stated, that from a small boiler a large amount of steam is produced. Another is that the stokehole is kept cool; and the third is that artificial blasts thus applied are unaccompanied by the dangers which arise, when under ordinary circumstances the blast is supplied only to the ashpit itself. The second marine engine to which I wish to call your attention is one that has been made with a view to great economy. The principles followed in its construction are among those suggested by the President (Sir W. G. Armstrong) in his address. He, you will remember, pointed out that the direction in which economy in the steam engine was to be looked for was that of increasing the initial pressure; although at the same time he said that there were drawbacks in the shape of greater loss, by radiation, and by the higher temperature at which the products of combustion would escape. We must admit the fact of the latter source of loss, when using very high steam, it being inevitable that the temperature of the products of combustion escaping from a boiler under these conditions must be higher than those which need be allowed to escape when lower steam is employed; although I regret to say that in practice, in marine boilers working at comparatively low pressures, the products are ordinarily suffered to pass into the funnel at above the temperature of melted lead. But with respect to the loss by radiation in the particular engine I am about to mention—that of Perkins—there is not as much loss as that which prevails in the ordinary marine boilers, because the Perkins boiler is completely enclosed, with the result that while there is within the case a boiler containing steam of 400 lbs. on the square inch, and the fire to generate that steam, the hand may be applied to the casing itself, which contains the whole of the boiler, without receiving any unpleasant sensation of warmth. By Mr. Perkins' arrangement, using steam of 400 lbs. in the boiler, it was found, as the result of very severe trials, conducted by Mr. Rich, of Messrs. Easton and Anderson's firm, and myself—trials which lasted for twelve hours—that the total consumption of fuel, including that for getting up steam from cold water, was just under 1.8, actually 1.79 lbs. per gross indicated horse power per hour. That gross indicated horse power was obtained in a manner which it is desirable should always be employed in steamboat trials. It was not got by using as a divisor the horse power of the most favorable diagram obtained during the day; but it was got from diagrams taken during the regular work; then, every half-hour, when the pressure began to die down from coal being no longer put upon the fire, diagrams taken every quarter of an hour, and then, towards the last, every five minutes; and the total number of foot pounds were calculated from these diagrams, and were used to obtain the gross indicated horse power.

Further, so far as could be ascertained by the process of commencing a trial with a known fire, and closing that trial at the end of six hours, with the fire as nearly as possible in the same condition, the consumption was 1.66 lbs. of coal per gross indicated horse power per hour. So that, without taking into account the coal consumed in raising steam from cold water, the engine worked for 1⅔ lbs. of coal per horse per hour. I think it well to give these details, because undoubtedly it is an extremely economical result. Our President alluded to the employment of ether as a means of utilizing the heat which escaped into the condenser, and gave some account of what was done by Mons. Du Tremblay in this direction. It so happened that I had occasion to investigate the matter at the time of Du Tremblay's experiments; very little was effected here in England, one difficulty being the Excise interference with the manufacture of ether. Chloroform was used here, and it was also suggested to employ bi-sulphide of carbon. In France, however, a great deal was done. Four large vessels were fitted with the ether engines, and I went over to Marseilles to see them at work. I took diagrams from these engines, and there is no doubt that, by this system, the exhaust steam from the steam cylinder, which was condensed by the application of ether to the surface of the steam condenser (producing a respectable vacuum of about 22 inches), gave an ether pressure of 15 lbs. on the square inch above atmosphere, and very economical results as regards fuel were obtained. The scheme was, however, abandoned from practical difficulties. It need hardly be said that ether vapor is very difficult to deal with, and although ether is light, the vapor is extremely heavy, and if there is any leakage, it goes down into the bilges by gravitation, and being mixed with air, unless due care is taken to prevent access to the fires, there would be a constant risk of a violent explosion. In fact, it was necessary to treat the engine room in the way in which a fiery colliery would be treated. The lighting, for instance, was by lamps external to the engine room, and shining through thick plate glass. The hand lamps were Davy's. The ether engine was a bold experiment in applied science, and one that entitles Du Tremblay's name to be preserved, and to be mentioned as it was by our President. There was another kind of marine engine that I think should not be passed over without notice; I allude to Howard's quicksilver engine. The experiments with this engine were persevered in for some considerable time, and it was actually used for practical purposes in propelling a passenger steam vessel called the Vesta, and running between London to Ramsgate. In that engine the boiler had a double bottom, containing an amalgam of quicksilver and lead. This amalgam served as a reservoir of heat, which it took up from the fire below the double bottom, and gave forth at intervals to the water above it. There was no water in the boiler, in the ordinary sense of the term, but when steam was wanted to start the engine, a small quantity of water was injected by means of a hand pump, and after the engine was started there was pumped by it into the boiler, at each half revolution, as much water as would make the steam needed. This water was flashed on the top surface of the reservoir in which the amalgam was confined, and was entirely turned into steam, the object of the engineers in charge being to send in so much water as would just generate the steam, but so as not to leave any water in the boiler. The engines of the Vesta were made by Mr. Penn, for Mr. Howard, of the King and Queen Ironworks, Rotherhithe. Mr. Howard was, I fear, a considerable loser by his meritorious efforts to improve the steam engine.

There was used with this engine an almost unknown mode of obtaining fresh water for the boiler. Fresh water, it will be seen, was a necessity in this mode of evaporation. The presence of salt, or of any other impurity, when the whole of the water was flashed into steam, must have caused a deposit on the top of the amalgam chamber at each operation. Fresh water, therefore, was needed; the problem arose how to get it; and that problem was solved, not by the use of surface condensation, but by the employment of re-injection, that is to say, the water delivered from the hot well was passed into pipes external to the vessel; after traversing them, it came back into the injection tank sufficiently cooled to be used again. The boilers were worked by coke fires, urged by a fan blast in their ashpits, but I am not aware that this mode of firing was a needful part of the system.

I come now to the *Engines used for railways.* At the British Association meeting of 1831, the Manchester and Liverpool Railway had been opened only about a year. The Stockton and Darlington coal line, it is true, had carried passengers by steam power as early as 1825, but I think we may look upon the

Manchester and Liverpool as being the beginning of the passenger and mercantile railway system of the present day. At that time the locomotives weighed from eight to ten tons, and the speed was about 20 miles per hour, with a pressure of from 40 to 50 lbs. The rails were light; they were jointed in the chairs, which were generally carried on stone blocks, thus affording most excellent anvils for the battering to pieces of the ends of the rails—that is to say, for the destruction of the very parts where they were most vulnerable. The engines were not competent to draw heavy trains, and it was a common practice to have at the foot of an incline a shed containing a "bank engine," which ran out after the trains as they passed, and pushed them up to the top of the hill. Injectors were then unknown, and donkey pumps were unknown, and therefore, when it was necessary to fill up the boiler, if it had not been properly pumped up before the locomotive came to rest, it had to run about the line in order to work its feed-pumps. To get over this difficulty, it was occasionally the practice to insert into a line of rails, in a siding, a pair of wheels, with their tops level with that of the rails so that the engine wheels could run upon the rims. Then, the locomotive being fixed to prevent it from moving of the pair of wheels thus endways it was put into revolution, its driving wheels bearing, as already stated, upon the rims of the pair of wheels in the rails, and thus the engine worked its feed pumps without interfering (by its needless running up and down the line) with the traffic. It should have been stated that at this time there was no link motion, no practical expansion of the steam, and that even the reversal of the engine had to be effected by working the slides by hand gear, in the manner in use in marine engines. When the British Association originated, although the Manchester and Liverpool Railway had been opened for a year, there is no doubt that the 300 members who then came to this City found their way here by the slow process of the stage-coach, the loss of which we so much deplore in the summer and in fine weather, but the obligatory use of which we should so much regret in the miserable weather now prevailing in these islands.

In 1831, we know that railways are everywhere inserted. Steel rails, double the weight of the original iron ones, are used. Wooden sleepers have replaced the stone blocks, and they, in their turn, will probably give way to sleepers of steel. The joints are now made by means of fishplates, and the most vulnerable part of the rail, the end, is no longer laid on an anvil for a purpose of being smashed to pieces, but the ends of the rails are now almost always over a void, and thereby are not more affected by wear than is any other part of the rail. The speed is now from 50 to 60 miles an hour for passenger trains, while slow speed goods engines, weighing 45 tons, draw behind them coal trains of 800 tons. The injector is now commonly employed, and, by its aid, a careful driver of the engine of a stopping train can fill up his boiler while at rest at the stations. The link motion is in common use, to which, no doubt, is owing the very considerable economy with which the locomotive engine now works.

As regards the question of safety, it is a fact that, notwithstanding the increased speed, railway accidents are fewer than they were at the slow speed. It is also a fact that, if the whole population of London were to take a railway journey, there would be but one death arising out of it. Four millions of journeys for one death of a passenger from causes beyond his own control is, I believe, a state of security which rarely prevails elsewhere. As an instance, the street accidents in London alone cause between 200 and 300 deaths per annum. This safety in railway traveling is no doubt largely due to the block system, rendered possible by the electric telegraph; and also to the efficient interlocking of points and signals, which render it impossible now for a signalman to give an unsafe signal. He may give a wrong one, in the sense of inviting the wrong train to come in; but, although wrong in this sense, it would still be safe for that train to do so. If he can give a signal, that signal never invites to danger; before he can give it, every one of the signals, which ought to be "at danger," must be "at danger," and every "point" must have been previously set, so as to make the road right; then, again, we have the facing point-lock, which is a great source of safety.

Further, we have continuous brakes of various kinds, competent in practice to absorb three miles of speed in every second of time; that is to say, if a train was going 60 miles an hour, it can be pulled up in twenty seconds; or, if at the rate of 30 miles, in 10 seconds. With a train running at 50 miles an hour, it can be pulled up in from 15 to 20 seconds, and in a distance of from 180 to 240 yards. Moreover, in the event of the train separating into two or more sections, the brakes are automatically applied to each section, thereby bringing them to rest in a short time. Another cause of safety is undoubtedly the use of weldless tyres. I was fortunate enough to attend the British Association Meeting many years ago at Birmingham, and I then read a paper upon weldless tyres, in which I ventured to prophesy that, in ten years' time, there would not be a welded tyre made; that is one of the few prophecies that, being made before the event, have been fulfilled. I may perhaps be permitted to mention, that at the same time I laid before the Section plans and suggestions for the making of the cylindrical parts of boilers equally without seam, or even welding. This is rarely done at the present time, but I am sure that, in twenty years' time, such a thing as a longitudinal seam of rivets in a boiler will be unknown. There is no reason why the successive rings of boiler shells should not be made weldless, as tyres are now made weldless.

The next subject I intend to deal with is that of *Motors*. In 1831, we had the steam engine, the water wheel, the wind mill, horse power, manual power, and Stirling's hot-air engines. Gas engines, indeed, were proposed in 1824, but were not brought to the really practical stage. We had then tide mills; indeed, we have had them until quite lately, and it may be that some still exist; they were sources of economy in our fuel, and their abandonment is to me a matter of regret. I remember tide mills on the coast between Brighton and New Haven, another between Greenwich and Woolwich, another at Northfleet, and in many other places. Indeed, such mills were used pretty extensively; they were generally erected at the mouth of a stream, and in that way the river bed made the reservoir, and even when they were erected in other situations, those were of a kind suitable for the purpose, that is, low lying lands were selected, and were embanked to form reservoirs. In 1881, wind mills and water wheels are much the same, but the turbines are greatly improved, and by means of turbines we are enabled to make available the pressure derived from heads of water which formerly could not be used at all, or if used, involved the erection of enormous water wheels, such as those at Glasgow and in the Isle of Man, wheels of some eighty feet in diameter. But now, by means of a small turbine, an excellent effect is produced from high heads of water. The same effect is obtained from the water engines which our President has employed with such great success. In addition to these motors, we have the gas engine, which, within the last few years only, has become a really useful working and economical machine. With respect to horse-power motors, we have not only the old horse engines, but we have a new application (as it seems to me) of the work of the horse as a motor. I allude to those cases where the horse drawing a reaping or threshing machine, not only pulls it forward as he might pull a cart, but causes its machinery to revolve, so as to perform the desired kind of work. This species of horse engine, though known, was but little used in 1831. With respect to hot-air engines there have been many attempts to improve them, and some hot-air engines are working, and are working with considerable success; but the amount of power they develop in relation to their size is small, and I am inclined to doubt whether it can be much increased.

I now come to the subject of the *transmission of power*. I do not mean transmission in the ordinary sense by means of shafting, gearing, or belting, but I mean transmission over long distances. In 1831, we had for this purpose flat rods, as they were called, rods transmitting power from pumping engines for a considerable distance to the pits where the pumps were placed, and we had also the pneumatic, the exhaustion system—the invention of John Hague, a Yorkshireman, my old master, to whom I was apprenticed—which mode of transmission was then used to a very considerable extent. The recollection of it, I find, however, has nearly died out, and I am glad to have this opportunity of reviving it. But in 1881, we have, for the transmission of power, first of all, quick moving ropes, and there is not, so far as I know, a better instance of this system than that at Schaffhausen. Any one who has ever, in recent years, gone a mile or two above the falls at Schaffhausen must have seen there—in a house, on the bank of the Rhine, opposite to that on which the town is situated—large turbines driven by the river, which is slightly damned up for the purpose. These work quick-going ropes, carried on pulleys, erected at intervals along the river bank, for the whole length of the town; and power is delivered from them to shafting below the streets, and from it into any house where it is required for manufacturing purposes. Then we have the compressed-air transmission of power, which is very largely used for underground engines, and for the working of rock drills in mines and tunnels. We have also compressed air in a portable form, and it is now employed with great success in driving tram cars. I had occasion last January to visit Nantes, where, for eighteen months, tramcars had been driven by compressed air, carried on the cars themselves, coupled with an extremely ingenious arrangement for overcoming the difficulties commonly attendant on the use of compressed air engines. This consists in the provision of a cylindrical vessel half filled with hot water and half with steam at a pressure of eighty pounds on the square inch. The compressed air, on its way from the reservoir to the engine, passes through the water and steam, becoming thereby heated and moistened, and in that way all the danger of forming ice in the cylinders was prevented, and the parts were susceptible of good lubrication. These cars, which start every ten minutes from each end, make a journey of 3¾ miles, and have proved to be a commercial and an engineering success. I believe, moreover, that they are capable of very considerable improvement. Then there is, although not much used, the transmitting of power by means of long steam pipes. There is also the transmission hydraulically. This may be carried out in an intermittent manner, so as to replace the reciprocating flat rods of old days; that is to say, if two pipes containing water are laid down, and if the pressure in those pipes at the one end be alternated, there will be produced an alternating and a reciprocative effect at the other, to give motion to pumps or other machinery. There is, also, that thoroughly well-known mode of transmission, hydraulically, for which the engineering world owes so much to our President. We have, by Sir William Armstrong's system, coupled with his accumulator, the means of transmitting hydraulically the power of a central motor to any place requiring it, and by the means of the principal accumulator, or if need be, by that aided by local accumulators, a comparatively small engine is enabled to meet very heavy demands made upon it for a short time. I think I am right in saying that, at the ordinary pressure which Sir William Armstrong uses in practice, viz., 700 lbs. to the square inch, one foot a second of motion along an inch pipe would deliver at the rate to produce one horse power. Therefore, a ten-inch pipe, with the water traveling at no greater pace than three feet in a second, would deliver 300 horse power. This 300 horse power would, no doubt, be somewhat reduced by the loss in the hydraulic engine, which would utilize the water. But the total energy received would be equivalent to producing 300 horse power. Such a transmission would be effected with an exceedingly small loss in friction in transit. I believe I am right in saying that a ten-inch pipe a mile long would not involve much more than about 14 or 15 lbs. differential pressure to propel the water through it at a rate of three feet in a second. If that be so, then, with 700 lbs. to the inch, the loss under such circumstances would be only two per cent. in transmission. There is no doubt that this transmission of power hydraulically has been of the greatest possible use. It has enabled work to be done which could not be done before. Enormous weights are raised with facility wherever required, as by the aid of power hydraulically transmitted, it is perfectly easy for one man to manage the heaviest cranes. Moreover, as I have said in other places, the system which we owe to Sir William Armstrong has gone far to elevate the human race, and it has done so in this manner. So long as it is competent for a man to earn a living by mere unintelligent exercise of his muscles, he is very likely to do it. You may see in the old London docks the crane heads covered by structures that look like paddle boxes. If you go to them, there is, I am glad to say, nothing now to fill them up; but when the British Association first met, these paddle boxes covered large tread wheels, in which the men trod, so as to raise a weight. Now, although I know that in fact there is nothing more objectionable in a man turning a wheel by treading inside of it than there is if he turn it round by a winch handle, yet somehow it strikes one more as being merely the work of an animal, a turnspit, or a squirrel, or indeed as the task imposed on the criminal. But, nevertheless, in this way there was a large number of persons getting their living by the mere exercise of their muscles, but, as might be expected, a very poor living, derived as it was from unintelligent labor. That work is no longer possible, and is not so, for the powerful reason that it does not pay. Those persons, therefore, who would now have been thus occupied, are compelled to elevate themselves, and to become competent to earn their living in a manner which is more worthy of an intelligent human being. It is on these grounds that I say we owe very much the elevation of the working classes, especially of the class below the artisan, to this invention of our distinguished President. In addition to the modes of transmission I have already mentioned, there is the transmission of power by means of gas. I think that there is a very large future indeed for gas engines. I do not know whether this may be the place to state it, but I believe the way in which we shall utilize our fuel hereafter will, in all probability, not be by the way of the steam engine. Sir William Armstrong alluded to this probability in his address, and I entirely agree, if he will allow me to say so, that such a change in the production of power from fuel appears to be impending, if not in the immediate future, at all events in a time not very far remote; and however much the Mechanical Section of the British Association may to-day contemplate with regret—even the mere distant prospect of the steam engine being a thing of the past, I very much doubt whether those who meet here fifty years hence will then speak of it as anything more than a curiosity to be found in a museum. With respect to the transmission of power electrically, I won't venture to touch upon that; but will content myself by reminding you that while Sir William Armstrong did say that there were comparatively small streams which could be utilized, he did not inform you of that which he himself had done in this direction; let me say that Sir William Armstrong thus utilized a fall of water, situated about a mile from his house, to work a turbine, which drives a dynamo machine, generating electricity, for the illumination of the house. When I was last at Crag Side, that illumination was being effected by the arc light, but since then, as Sir William Armstrong has been good enough to write to me, he has replaced the arc light by the incandescent lamp (a form of electrical lighting far more applicable than the arc light to domestic purposes), and with the greatest possible success. Thus, in Sir William Armstrong's own case, a small stream is made to afford light in a dwelling a mile away. Certainly nothing could have seemed more improbable fifty years ago than that the light of a house should be derived from a fall of water, without the employment of any kind or description of fuel.

The next subject upon which I propose to touch, is that of the *Manufacture of iron and the steel.* In 1831, Nelson's hot blast specification had been published for 2½ years only. The Butterly Company had tried the hot blast for the first time in the November preceding the meeting of the British Association. The heating of the blast was coming very slowly into use, and the temperature attained when it was employed was only some 600 degrees. The ordinary blast furnace of those days was 35 to 40 feet high, and about 12 feet diameter at the boshes, and turned out about 60 tons a week. It used about 2½ tons of coal per ton of iron, and no attempt was made to utilize the waste gases, whether escaping in the form of gas or in the form of flame, the country being illuminated for miles around at night by these fires. The furnaces were also open at the hearth, and continuous fire poured out along with the slag. In 1881, blast furnaces are from 90 ft. to 100 ft. high, and 25 ft. in diameter at the boshes; they turn out from 500 to 800 tons a week. The tops and also the hearths are closed, and the blasts—thanks to the use of Mr. E. A. Cowper's stoves—is at 1,200 degrees. The manufacture of iron has also now enlisted in its service the chemist as well as the engineer, and amongst those who have done much for the improvement of the blast furnaces, to no one is greater praise due than to Mr. Isaac Lowthian Bell, who has brought the manufacture of iron to the position of a highly scientific operation. In the production of wrought iron by the puddling process, and in the subsequent mill operations, there is no very considerable change, except in the magnitude of the machines employed, and in the greater rapidity with which they now run. In saying this, I am not forgetting the various "mechanical puddlers" which have been put to work, nor the attempts that have been made by the use of some of them to make wrought iron direct from the ore; but neither the "mechanical puddler" nor the "direct process" have yet come into general use; and I desire to be taken as speaking of that which is the ordinary process pursued at the present in puddled iron manufactures. In 1831, a few hundred weights was the limit of weight of a plate, while in 1881, there may readily be obtained, for boiler-making purposes, plates of at least four times the weight of those that were made in 1831. I may, perhaps, be allowed to say that there is an extremely interesting Blue Book of the year 1818, containing the report of a Parliamentary Committee which sat on boiler explosions, and I recommend any mechanical engineer who is interested in the history of the subject to read that book; he will find it there stated that in the North of England there were a species of engines called locomotives, the boilers of which were made of wrought iron beaten, not rolled, because the rolled plate was not considered fit; it was added that if made of beaten iron the boiler would last at least a year. In 1831, thirteen years later, the dimensions of rolled plates were, no doubt, raised; but few then would have supposed it possible there should be rolled such plates as are now produced for boiler purposes, and still fewer would have believed that in the year 1881 we should make, for warlike purposes, rolled plates 22 inches in thickness and 30 tons in weight. I have said there is very little alteration in the process of making wrought iron by puddling, and I do not think there is likely to be much further, if any, improvement in this process, because I believe that, with certain exceptions, the manufacture of iron by puddling is a doomed industry. I ventured to say, in a lecture I delivered at the Royal Institution three years ago on "The Future of Steel," that I believed puddled iron, except for the mere hand-wrought forge purposes of the country blacksmith, and for such like purposes, would soon become a thing of the past. Mr. Harrison, the engineer of the North-Eastern Railway, told me that, about eighteen months ago, the North-Eastern Railway applied for tenders for rails in any quantities between 2,000 and 10,000 tons, and they issued alternative specifications for iron and for steel. They received about ten tenders. Some did not care to tender for iron at all; but when they did tender alternatively, the price quoted for the iron was greater than that for the steel. I have no doubt whatever, that in a short time it will be practically impossible to procure iron made by the puddling process, of dimensions fit for many of the purposes for which a few years ago it alone was used. With respect to steel: In 1831, the process in use was that of cementation, producing blistered steel, which was either piled and welded to make sheer steel, or was broken into small pieces, melted in pots, and run into an ingot weighing only some 50 lbs. or 60 lbs. At that time, steel was dealt in by the pound; nobody thought of steel in tons. In 1881, we are all aware that, by Sir Henry Bessemer's well-known discovery, carried out by him with such persistent vigor, cast iron is, by the blowing process, converted into steel, and that, by Dr. Siemen's equally well-known process (now that, owing to his invention of the regenerative furnace, it is possible to obtain the necessary high temperature), steel is made upon the open hearth. We are, moreover, aware that, by both of these processes, steel is produced in quantities of many tons at a single operation, with the result that, as instanced in the case of the North-Eastern rails, steel is a cheaper material than the wrought iron made by the puddling process. One cannot pass away from the steel manufacture without alluding to Sir Joseph Whitworth's process of putting a pressure on the steel while in a tried state. By this means, the cavities which are frequently to be found in the ingot of a large size, are, while the steel is fluid, rendered considerably smaller, and the steel is thereby rendered much more sound. In conclusion of my observations on the subject of iron and steel manufacture, I wish to call attention to the invention of Messrs. Thomas and Gilchrist, by which ores of iron, containing impurities that unfitted them to be used in the manufacture of steel, are now freed from these impurities, and are thus brought into use for steel-making purposes.

Bridges.—In the year 1831, bridges of cast iron existed; but no attempt had been made to employ wrought iron in girder bridges, although Telford had employed it in the Menai Suspension Bridge; but in 1881, the introduction of railways, and the improvement in iron manufactures, have demanded, and have rendered possible the execution of such bridges as the tubular one, spanning the Menai Straits, in span of 400 feet, and the Saltash, over the Tamar, with spans of 435 feet; while recent great improvements in the manufacture of steel have rendered possible the contemplated construction of the Forth Bridge, where there are to be spans of 1,700 feet, or one-third of a mile in length. Mr. Barlow, one of the engineers of this bridge, has told me that there will be used upwards of 2,000 more tons of material in the Forth Bridge, to resist the wind pressure, than would have been needed if no wind had to be taken into account, and if the question of the simple weight to be carried had alone to be considered. With respect to the foundation of bridges, that ingenious man, Lord Cochrane, patented a mode of sinking foundations, even before the first meeting of the British Association, viz., as far back, I believe, as 1825 or 1826; and the improvements which he then invented are almost universally in use in bridge construction at the present day. Cylinders sunk by the aid of compressed air, airlocks to obtain access to the cylinder, and in fact every means that I know of as having been used in the modern sinking of cylinder foundations, were described by Lord Cochrane (afterwards Earl of Dundonald) in that specification.

The next subject I propose to touch on, is that of *Machine Tools*. In 1831, the mention of lathes, drilling machines, and screwing machines, brings me very nearly to the end of the list of the machine tools used by turners and fitters, and at that time many lathes were without slide rests. The boilermaker had then his punching press and shearing machine; the smith, leaving on one side his forges and their bellows, had nothing but hand tools, and the limit of these was a huge hammer, with two handles, requiring two men to work it. In anchor manufacture, it is true, a mechanical drop-hammer, known as Hercules, was employed, while in iron works, the Helve and the Tilt hammer were in use. For ordinary smith's work, however, there were, as has been said, practically no machine tools at all.

This paucity or absence in some trades, as we have seen, of machine tools, involved the need of very considerable skill on the part of the workman. It required the smith to be a man not only of great muscular power, but to be possessed of an accurate eye and a correct judgment, in order to produce the forgings which were demanded of him, and to make the sound work that was needed, especially when that soundness was required in shafts, and in other pieces which, in those days, were looked upon as of magnitude; which, indeed, they were, relatively to the tools which could be brought to operate upon them. The boiler maker in his work had to trust almost entirely to the eye for correctness of form and for regularity of punching, while all parts of engines and machines which could not be dealt with in the lathe, in the drilling, or in the screwing machine, had to be prepared by the use of the chisel and the file.

At the present day, the turning and fitting shops are furnished, not only with the side lathe, self-acting in both directions, and screw-cutting, the drilling machine. and the screwing machine, but with planing machines competent to plane horizontally, vertically, or at an angle; shaping machines, rapidly reciprocating, and dealing with almost any form of work; nut-shaping machines, slot-drilling machines, and slotting machines, while the drills have become multiple and radial; and the accuracy of the work is ensured by testing on large surface plates, and by the employment of Whitworth internal and external standard guages.

The boiler-maker's tools now comprise the steam, compressed air, hydraulic or other mechanical riveter, rolls for the bending of plates while cold into the needed cylindrical or conical forms, multiple drills for the drilling of rivet holes, planing machines to plane the edges of the plates, ingenious apparatus for flanging them, thereby dispensing with one row of rivets out of two, and roller expanders for expanding the tubes in locomotive and in marine boilers; while the punching press, where still used, is improved so as to make the holes for seams of rivets in a perfect line, and with absolute accuracy of pitch.

With respect to the smith's shop, all large pieces of work are now manipulated under heavy Nasmyth or other steam hammers; while smaller pieces of work are commonly prepared either in forging machines or under rapidly moving hammers, and when needed in sufficient numbers are made in dies. And applicable to all the three industries of the fitting shop, the boiler shop, and the smith's shop, and also to that other industry carried on in the foundry, are the traveling and swing cranes, commonly worked by shafting, or by quick-moving ropes for the travelers, and by hydraulic power or by steam engines for the swing cranes. It may safely be said that, without the aid of these implements it would be impossible to handle the weights that are met with in machinery of the present day.

I now come to one class of machine which, humble and small as it is, has probably had a greater effect upon industry and upon domestic life than almost any other. I mean the *Sewing Machine*. In 1831, there was no means of making a seam except by the laborious process of the hand needle. In 1846, Eldred Walker patented a machine for passing the basting thread through the gores of umbrellas, a machine that was very ingenious and very simple, but was utterly unlike the present sewing machine, with its eye-pointed needle, using sometimes two threads (the second being put in by a shuttle or by another needle), and making stitches at twenty fold the rapidity with which the most expert needle-woman could work. By means of the sewing machine not only are all textile fabrics operated upon, but even the thickest leather is dealt with, and as a *tour de force*, but as a matter of fact, sheet-iron plates themselves have been pierced, and have been united by a seam no boiler-maker ever contemplated, the piercing and the seam being produced by a Blake sewing machine. I believe all in this Section will agree that the use of the sewing machine has been unattended by loss to those who earn their living by the needle; in fact, it would not be too much to say that there has been a positive improvement in their wages.

The next matter I have to touch upon is *Agricultural machinery*. In 1831, we had threshing machines and double plows, and even multiple plows had been proposed, tried and abandoned. Reaping machines had been experimented with and abandoned; sowing machines were in use, but not many of them; clod crushers and horse rakes were also in use; but as a fact plowing was done by horse power with a single furrow at a time; mowing and reaping were done by the scythe or the sickle, sheaves were bound by hand, hay was tedded by hand rakes, while all materials and produce were moved about in carts and in wagons drawn by horses. At the present time we have multiple plows, making five or six furrows at a time, these and cultivators, also driven by steam, commonly from two engines on the head lands. the plow being in between, and worked by a rope from each engine, or if by one engine, a capstan on the other head land, with a return rope working the plow backwards and forwards; or by what is known as the round-about system, where the engine is fixed and the rope carried round about the field; or else plows and cultivators are worked by ropes from two capstans placed on the two head lands, and driven by means of a quick-going rope, actuated by an engine, the position of which is not changed. And then we have reaping machines, driven at present by horses; but how long it will be before the energy residing in a battery, or that in the reservoir of compressed air, will supersede horse power to drive the reaping machine, I don't know, but I don't suppose it will be very long. The mowing and reaping machines not only cut the crop and distribute it in swathes, or, in the case of the reaping machines, in bundles, but now, in the instance of these latter machines, are competent to bind it into sheaves. In lieu of hand tedding, hay-making machines are employed, tossing the grass into the air, so as to thoroughly aerate it, taking advantage of every brief interval of fine weather; and seed and manure are distributed by machines with unfailing accuracy. The soil is drained by the aid of properly constructed plows for preparing the trenches; roots are steamed and sliced as food for cattle; and the threshing machine no longer merely beats out the grain, but it screens it, separates it, and elevates the straw, so as to mechanically build it up into a stack. I do not know a better class of machine than the agricultural portable engine. Every part of it is perfectly proportioned and made; it is usually of the locomotive type, and the economy of fuel in its use is extremely great. I cannot help thinking that the improvement in this respect which has taken place in these engines, and the improvement of agricultural machinery generally, is very largely due to the Royal Agricultural Society, one of the most enterprising bodies in England.

I now come to the very last subject I propose to speak upon, and that is *Printing machinery*, and especially as applied to the printing of newspapers. In 1831, we had the steam press sending out a few hundred copies in an hour, and doing that upon detached sheets, and thus many hours were required for an edition of some thousands. The only way of expediting the matter would have been to have recomposed the paper, involving, however, double labor to the compositors, and a double chance of error. At the present day, we have, by the Walter press, the paper printed on a continuous sheet at a rate per hour at least three times as great as that of the presses of 1831, and, by the aid of *papier mache* moulds, within five minutes from the starting of the first press, a second press can be got to work from the stereotype plates, and a third one in the next five minutes; and thus the wisdom of our senators, which has been delivered as late as three o'clock in the morning, is able to be transmitted by the newspaper train leaving Euston at 5:15 A. M.

This is the last matter with which I shall trouble the Section. I have purposely omitted telegraphy; I have purposely omitted artillery, textile fabrics, and the milling and preparation of grain. These and other matters I have omitted for several reasons. Some I have omitted because I was incompetent to speak upon them, others because of the want of time, and others because they more properly belong to Section A.

I hope, sir, although your address, dealing with the future, was undoubtedly the right address for a President to deliver, and although it is equally right that we should not content ourselves with merely looking back in a "rest-and-be-thankful" spirit at the various progress which this paper records, it may nevertheless be thought well that there should have been brought before the Section, in however cursory a manner, some notice of mechanical development during the past fifty years.

Dr. Phipson recently communicated to the Académie des Sciences, Paris, a note expressing his belief that commercial zinc generally contains some small proportion of another metallic element, for which the author proposes the term *actinium* to characterize its curious actinic phenomena. Precipitating the metal with sulphide of barium, washing, drying, and calcining, a white sulphide of zinc is obtained, which, under the influence of the direct solar rays, changes in about thirty minutes to a slate color, but returns to the original white if kept again in darkness, but with free access of air. The phenomenon does not occur, the *Chemist and Druggist* says, however, if the solar rays pass through glass.

THE PREVENTION OF WASTE OF WATER.*

By THOMAS STEWART, Stud. Inst. C.E.

From Selected Papers of the Institution of Civil Engineers.

The prevention of the waste of water has of late years received considerable attention from engineers in charge of the supply and distribution of water in towns. Various circumstances have led to this, the chief being that new works which had been expected to afford ample supplies to the towns for whose use they had been designed have proved insufficient; and it has become necessary to consider what steps should be taken to meet the emergency. One way is to give an intermittent supply; another, to extend the works. The former method is gradually going out of use on account of the sanitary evils which accompany it. The latter is not always practicable, as the resources may be exhausted; or, if water be available, the cost of introducing it may be excessive.

In order to avoid the expense of new works on the one hand, and the evils of an intermittent supply on the other, attention has been directed to the causes of the increased consumption, and while it has been found that the quantity of water legitimately used has been slowly on the increase, it has also been found that the greater part of the increase in the consumption is due to waste from defective pipes and fittings belonging to the consumers.

Waste throughout this paper is applied to water which flows from defects in the service pipes and fittings, and does not include the waste due to extravagance in the use of water.

In order to give corporations and water companies some control over the consumers' pipes and fittings, several general Acts of Parliament have been passed. These have been of use when the prevention of waste was not urgent; but when strong action has been required, special Acts have been found necessary. Under such Acts numerous towns have succeeded in reducing the waste to so great an extent, that their insufficient supplies have been converted into abundant ones, without interfering with the quantity of water required.

In carrying out operations for the prevention of waste, much information has been obtained regarding the sources of waste and its extent. In this paper the author describes the sources of waste, the regulations as to apparatus for preventing it; methods employed for the detection and prevention of waste, and the results obtained.

I.—Sources of Waste.

These may be divided into three classes:

(1) Defective water fittings.
(2) Defective service pipes.
(3) Defective distributing pipes.

(1.) *Defective water fittings.*—These have always been the most fruitful sources of waste, and being chiefly inside houses and often in out-of-the-way corners, they are not readily seen by water inspectors. The occupants seldom trouble themselves about waste so long as water does not squirt about the house or annoy them by its noise. Previous to engineers prescribing in detail the uses and kinds of water fittings to be employed, plumbers were in the habit of putting in very inferior articles, cheapness in their estimation being of more consequence than first-class work. Except in the better-regulated water works, this practice was general throughout the country until within about the last twenty-five years. However, the prescribing of the kinds of fittings, and testing and stamping them, are making a great improvement in this matter; but where special measures have been resorted to of late years for the prevention of waste, these old and imperfect fittings have been a continual source of annoyance, and except in rare cases, where there are powers for compelling their removal, have retarded the operations. These defective fittings consisted chiefly of ground cocks and water-closets supplied direct from the main by taps. In three or four months after being put on, the ground cocks were found wasting water, and at any time

* This communication was read and discussed at a meeting of the students on the 8th of April, 1881, and has been awarded a Miller prize.

the taps to the water-closets allowed a continuous flow. Before 1860 these classes of water fittings had ceased to be used in well-regulated water works. In Glasgow they were prohibited shortly after the introduction of water from Loch Katrine in 1860. On account of the consumption rising at an extraordinary rate during the summer of that year, Mr. Bateman, Past President Inst. C.E, drew the attention of the corporation to the matter. Mr. Gale, M. Inst., C.E., engineer to the Water-works Commissioners, made a special inspection of the fittings in several parts of the town, and he found that the greatest waste was from common ground ball-cocks in cisterns; fifty-three of these were found wasting 12,500 gallons per day, and ninety-nine common ground stop cocks were wasting 11,700 gallons. At this time three-fourths of the total number of cocks in use were of the common ground kind.

The result of Mr. Gale's investigations led to the following rules:

(1) "That no common ground cock be allowed for the future to be supplied direct from the main service pipe or from a cistern, except it be on the same floor as the tap, and that screw-down cocks only be used for this purpose.

(2) "That no water closet be allowed to be supplied direct from the main service pipe by any kind of tap, but be supplied from cisterns."

By enforcing these rules, and by the aid of a system of rigid house-to-house inspection, a saving of 5,000,000 gallons per day, or 11 gallons per head per day, was effected, and this continued until the commissioners relaxed the regulations.

In 1864, in order to ascertain how many of the existing fittings complied with the requirements of the above rules, an examination of the whole water fittings was made. The kinds which did not comply amounted to 41 per cent. of the whole, and during the examination every eighth tap was found wasting water.

The Water Company of Norwich, working under their special Act of Parliament of 1859, reduced the consumption from about 40 gallons to less than 14½ gallons per head per day. Mr. Ayris, M. Inst. C. E., the manager, attributed one-half of this saving to the introduction of screw-down cocks, and the other half to abolishing cocks to water closets and ground ball cocks to cisterns.

Newcastle affords another example of great saving by adopting proper taps and water closets. Mr. Main, the manager, in his evidence on the East London Water works Bill, 1867, states that on account of the flagrant waste from badly constructed taps and water closets, a rigid inspection was instituted, and the proprietors were called upon to make the necessary repairs and alterations. In one district after double-valve cisterns had been put into every house, the consumption fell from 32½ to 16½ gallons per head per day.

(2) *Defective service pipes.*—These are not so numerous as defective fittings in proportion to the number of persons supplied; but while the waste from them is not so great, the possibilities of discovering it are fewer on account of the pipes being in great part underground. Except when a service pipe bursts inside a house, thereby causing damage, the waste from this source is apt to be continuous, unless there is a want of pressure in the houses, or the water shows at the surface. As an instance, in Glasgow, during 1876, of 10,825 complaints of want, or information of waste, of water received, 3,294 were found to be caused by burst lead service pipes.

Service pipes are usually of lead, and may be defective by being too light for the pressure, by bad material being used in their construction, or by inferior workmanship. The lightness and bad material may be detected by inspecting the pipes before they are covered up, and in some cases so may the inferior workmanship; but owing to splits occurring in the inside of the pipe during manufacture, and not appearing on the outside, the difficulty of ensuring the absence of defects of this sort is great.

When the pipes are of iron, it is usually stipulated that they shall be subjected to a certain pressure before being used, and the laying of them is superintended by an officer from the water works. In some towns, such as Rochdale, Carlisle, and others, it is the practice for the corporation to lay the service pipes up to or through the boundary wall, while in other towns the proprietors' plumbers lay the service pipes to the mains.

It frequently happens that on a new supply being introduced to towns, the pressure is much increased, and this causes the service pipes, which may have been sufficiently strong for the old state of things, to give way. Norwich, Dublin,* and Glasgow afford instances of an increased supply acting injuriously on the old service pipes. Unless special powers have been secured for compelling the removal of such service pipes, the reduction of waste is a slow process.

(3) *Defective distributing pipes.*—The remarks made in reference to defective service pipes are in great part applicable to distributing pipes. When newly laid they are usually tight, and the quality of the pipes is insured by the water companies specifying the proportions of metal to be used, and superintending the making and testing of them. They become defective by local subsidence of the pipe-track, causing blown joints and splits in the pipe, and by defects not always capable of being explained. Defects in them are discovered by the water rising to the surface, or, when not rising and the waste is great, by want of pressure in the locality. Waste from this source has been known to continue for years without showing any signs on the surface or causing a defective supply, and Mr. Deacon, M. Inst., C. E.,† states that he has seen the edges of the cracks in the pipes worn smooth by the continual action of the water. In Glasgow two defects were recently discovered by the falling in of the surface of the street: the water in each case had made its way into the sewer, and in one instance had formed a tunnel large enough for a man to walk from the sewer to the main. In the other instance five cart-loads of material were required to fill up the cavity. The defects were on 3-inch and 4-inch pipes respectively. There were no reliable data to show how long the leaks had been in existence.

(1) *Regulations for securing proper service pipes and fittings.*—For the purpose of securing proper service pipes and water fittings, engineers of water works have been for some time in the habit of prescribing the classes and qualities to be adopted. In order the better to secure these ends, some towns, including Blackburn, Norwich, Yarmouth, Rochdale and Preston, do the greater part of the work themselves; others issue specifications, and make contracts with brassfounders for the supply of the necessary fittings; while others keep samples, to which all apparatus must conform, and, in addition, most of them test and stamp approved fittings. Manchester, Liverpool, Bolton, Glasgow and Dublin test and stamp. The system was first introduced at Manchester. There are modifications in the details of the system as carried out in the various towns, but the following regulations are common to most: Prescribing the kinds and qualities of the fittings to be used; keeping samples, to which all fittings must conform; weighing and gauging certain parts of the fittings; subjecting cocks to a pressure about three times as great as that which they will have to stand when in use; examining water-closet cisterns to ascertain that they give a flush of 1½ gallons or 2 gallons within three or four seconds; stamping approved apparatus; charging a small fee for the work.

These measures ensure that water fittings of good quality are used, and they have led to cocks constructed on screw-down principles being the rule. Water-closet cisterns have now to be made so that not more than 2 gallons of water can be used at a single flush, thus abolishing the evil of having the water running for a certain time by tying up the handle.

(2) *Regulations regarding water fittings in Glasgow.*—By the Glasgow Corporation Water works Act, 1856, the Water works Commissioners have powers to make by-laws for the prevention of waste and misuse of the water, and to impose penalties for breaches of such by-laws. The Act of 1859 provides that all apparatus in use, or proposed to be used, shall be subject to the approval of the engineer to the commissioners.

The regulations made in 1860 have been gradually amended, the most important additions being the recommendation of double-valve cisterns to water closets in 1868, and in 1873 the insisting on cisterns giving no more than 2 gallons at a flush. In October, 1875, certain classes of fittings were proscribed because they were not of the waste-preventing kind. A list of these is given in Appendix I. When found wasting water twice in three months, they have to be removed, and they are not allowed to be fitted up

* *Vide* Minutes of Proceedings Inst. C. E., vol. xxxviii., p. 48.

† *Vide* Minutes of Proceedings Inst. C. E., vol. xlii., p. 156.

in new premises. In 1876 it was resolved that overflow pipes should be brought outside the building, or made to discharge inside, so that the water could not escape without being seen. In April, 1877, lead service pipes under the regulation weight were proscribed. At present, when found wasting water twice in six months, they must be removed, so far as they are underground or in unoccupied cellars. In 1877 the system of testing and stamping was introduced. With some modifications in detail it is the same as carried out in other towns, Cocks to be supplied direct from the main are tested to a pressure of 300 lbs., and ball-cocks for cisterns to a pressure of 150 lbs. per square inch. Lavatory and other fittings, supplied off cisterns, are tested to a pressure of 25 lbs. The fittings which fulfill all the requirements are stamped.

The following table shows the improvement effected in the manufacture of the fittings since the introduction of the system of testing and stamping:

Year.	Number Examined.	Number Rejected.	Per cent. Rejected.
1877	4,369	640	14.60
1878	26,931	1,710	6.30
1879	24,300	989	4.07
1880	27,517	1,081	3.92

The regulations specify the service pipes to be of lead, and, unless otherwise specially agreed upon, no other kinds are permitted. The following are the weights per yard; ½-inch, 7 lbs.; ¾-inch, 10 lbs.; 1-inch, 14 lbs.; 1¼-inch, 18 lbs.; 1½-inch, 24 lbs.

When the service pipes are allowed to be of cast iron, they must be of the following dimensions and weights:

Diameter of Pipe.	Thickness of Pipe.	Depth of Socket.	Length of Pipe, exclusive of Socket.	Mean Weight of each Pipe.		
Inches.	Inch.	Inches.	Feet.	Cwt.	qrs.	lbs,
4	⅜	3	9	1	1	25
3	⅜	3	9	1	0	17
2	⅜	3	6	0	2	4

The greatest pressure to which these pipes are likely to be subjected under ordinary circumstances is about 100 lbs. per square inch, but the pressure which causes most pipes to burst, viz., that due to shutting taps, is not so easily ascertained.

(3) *Work in connection with supply to premises.*—No pipe or fitting is allowed to be covered up until an inspector has ascertained that it fulfills all the required conditions. Service pipes must be provided with stop-cocks about 2 feet from where they leave the distributing pipe, and must be laid 2 feet 6 inches below the surface; where exposed, they must be properly protected against frost.

Where cisterns have to be provided for the ordinary supply, a ball-cock is put on and so adjusted as to shut when the water is 2 inches from the top of the overflow pipe.

Screw-down cocks only are used when supplied direct from the main, or from a cistern on any other than the same floor. Common ground cocks and ground cocks with stuffing boxes may be used where the supply is from a cistern on the same floor, or, in "self-contained" houses, in the floor above. Water-closets and urinals are provided with cisterns having waste-preventing apparatus, so constructed that in water-closets not more than 2 gallons can be used at a single flush, and in urinals not more than ½ a gallon. "Waste not," or self-closing cocks, may be used for supplying the latter. Wells in courts and taps on stairs must be self-closing.

II.—Methods for Detecting and Preventing Waste.

(1) *House-to-house inspection*, the oldest and most common method for detecting waste, is in use in most of the larger towns throughout the kingdom, in some of which it is the only method employed; elsewhere it is used in conjunction with meters and other appliances. As carried out in most towns it consists in dividing the town into districts and appointing an inspector to each district, whose duties are to regularly visit the houses, inspect the water fittings in each house, and take a note of those wasting water. Thereafter a notice is left with the tenant, or one is sent to the owner, informing him of the defective state of the fitting, and calling upon him to make the repairs within a certain number of days. Some

water companies and corporations repair the washers and other small articles free of charge, but in these cases the water fittings are of one maker's patterns. The inspector examines the defective fittings a second time within a certain number of days. If the repairs are not executed the water is shut off, or the inspector reports the matter to the engineer, who then orders his plumbers to execute the repairs, and charges the cost to the owner. The practice of making the repairs and charging the cost to the owner is not largely followed, as disputes continually arise, either regarding the correctness of the charge or the proper person to be charged.

There can be no doubt that to shut off the water at the stop-cock is the most effectual appeal to the parties liable. The practice at first sight appears somewhat arbitrary, as there are at times more than eight tenants to one stop-cock, seven of whom may be ignorant of anything being wrong. This may be partly remedied, if the repairs are delayed too long, by beating up the pipe leading to the offending tap, or by locking up the tap itself, assuming, of course, that either of these courses is practicable.

In Glasgow the practice is for the inspector, during his first inspection, to enter in a book a description of the fittings found wasting, and to take a note of those in good repair. On the evening of the same day a notice is sent to the owner or factor, as the case may be, calling upon him to effect the repairs within two days. The inspector makes his second inspection within six days after. If the repairs are not made, the bad tap is locked up, or, if this cannot be done, the water is shut off at the stop-cock. The pipe leading to the tap, &c., might be beaten up, and thus save the other tenants annoyance, but the proceeding causes damage to woodwork and plaster. This is done, and the water restored to the other tenants, if the repairs are delayed beyond a reasonable time. When much water is running to waste the inspector shuts it off during his first inspection. Special reports are made on lead pipes found burst twice in six months, and on the proscribed fittings enumerated in Appendix I.

That the system of house-to-house inspection is valuable in preventing waste is proved by the numerous instances in which, when combined with the removal of bad fittings, the consumption has been reduced by one half. Manchester, Cambridge, and Newcastle, afford well-known instances. In Glasgow, in 1873, an addition of four inspectors was made to the staff, raising the number to twelve. In that year the average consumption of water per day was 800,000 gallons less than during the previous year. Part of this decrease was no doubt due to the increased number of inspectors.

(2) *District meter system.*—As the system of house-to-house inspection does not localize the sources of waste, all the districts receive the same attention, and as experience has proved that the waste varies much in different districts, attention is thereby thrown away. To obviate this, and to enable the worst districts to receive the most attention, meters have been put on the distributing pipes supplying these. By registering the quantity of water passing they enable those in charge to ascertain whether the consumption is above or below the average—assuming that the population in each district is known.

The meters used for this purpose may be divided into two classes, namely, ordinary meters, or such as register by an index the total quantity of water passed in a certain time; and automatic registering meters, which by means of diagrams show the rate of consumption at any hour or part of an hour.

Ordinary meters.—Of the numerous meters belonging to this class, Kennedy's piston meter and Siemens' turbine meter are the best known. Neither of these is intended for detecting waste; but notwithstanding, both of them have been, and are still, used to a considerable extent. As neither of these meters of itself registers the flow of water at a particular time, it is necessary, should this be wanted, to station an observer by the meter for the purpose of reading the index at the required intervals. It is an important peculiarity of the district meter system that the effect of shutting a pipe or tap through which water is passing shall be shown by the meter. This ordinary meters fail to do in a sufficiently clear manner, unless the waste has been excessive. However, they give a more reliable account of the total quantity passed in a certain number of hours than the meters which register by diagram.

In Newcastle several districts were put under the control of ordinary meters; in four of these at the starting of the meters the consumption of water was at the rate of 55, 60, 61, and 62 gallons per head per day; after the repairs and renewal of fittings and service pipes had been carried out, the consumption in the four districts was at the rate of 34, 39, 25, and 26 gallons respectively.*

In Liverpool in 1872,† fourteen districts, containing 31,080 persons, were put under the control of as many ordinary piston meters. The locality of the waste was determined by "sounding" the stop-cocks at night, and next day inspecting the premises where water had been found passing. After several of the day and night inspections had been made in each of the districts, the consumption, which before the starting of the meters had been, under nine hours (intermittent) service, 19.5 gallons, and under constant service, 33.5 gallons was reduced, under constant service, to about 12 gallons. These quantities are exclusive of water used for trade purposes.

In Glasgow, about the same time, similar experiments had been made by placing three of Siemens' meters on as many districts; the first district contained 738 persons, the second 2,299, and the third 1,391. The effect of the repairs was to reduce the total consumption in the first district from 60 to 38 gallons per head per day; in the second from 45 to 20; and in the third from 77½ to 50 gallons.

The sources of waste were ascertained to be burst service pipes, water-closets supplied by various kinds of taps direct off the main, and common ground cocks. The distributing pipes were tight in all the districts.

Automatic meters registering by diagrams.—These are now being largely employed for the purpose of checking waste by localizing its sources. Some experiments have been made with Kennedy's and with Tylor's meters, which in addition to the recording index have been provided with diagrams, but their use has not become general. The one in ordinary use is the waste-water meter, invented by Mr. Deacon, M. Inst. C.E., engineer of the Liverpool waterworks, and first applied by him to districts in that town.‡

* *Vide* Evidence on East London Water Works Bills, 1867.
† *Vide* Min. of Proceedings Inst. C.E., vol. xlii., p. 140.
‡ *Ibid.*, vol. xlii., pp. 148-160.

In October, 1873, the first meter was fixed in Liverpool; by the 10th of April, 1875, one hundred and twenty meters were fixed, having under control 306,912 persons; of these, districts containing 117,425 persons had received most attention, and the consumption, which under constant service had been 32.12 gallons, was reduced to 15.9 gallons per head per day. In 1865 intermittent service had to be given on account of the increased consumption; but in 1875 the result of the operations connected with the meter system enabled the constant supply to be restored to nearly the whole area of supply. On the 26th of January, 1881, two hundred and five meters were in operation, having under control 705,146 persons, and the average consumption before the frost had set in was 21½ gallons per head per day, including supplies for all purposes; deducting the water sold for trade purposes the rate was 13½ gallons.

The waste-water meter was applied to a large district in Glasgow in April, 1876, and afterwards the system was extended to other districts in various parts of the town. The method followed for reducing the waste differs considerably in details from that pursued in Liverpool, partly because the arrangement of the distributing pipes and dwelling houses is different, and partly because the conditions of supply are not comparable. The following description may therefore be permissible,

While the experiments with the three Siemens' meters were being made, a fourth district containing 667 persons was put under the control of a waste-water meter. After the repairs which followed the first night inspection had been effected, the consumption of water fell from 65½ to 41 gallons per head per day, and the rate between 1 A. M. and 5 A. M., from 57 to 31 gallons per head. On the strength of these results, Mr. Gale recommended a large experimental district to be proceeded with, and the waste-water meter to be used.

Districts.— The experimental district selected contains 14,972 persons. It was divided into nine sub-districts, on each of which a meter was placed. A year after the meters had been put in working order, the results were, by Mr. Gale, considered sufficient to warrant the extension of the system to nine additional districts. The last meter was fixed in August, 1878.

The additional districts were divided into forty-one sub-districts, and the piping in forty of them was put under the control of waste-water meters; the piping in one sub-district was put under the control of a Kennedy's piston meter, provided with a self-registering apparatus and diagram, Figs. 1, 2, and 3.

In selecting the districts, every endeavor was made to include as many varieties of house property as possible, and to exclude the business and manufacturing parts of the town. The property controlled by the meters embraces various classes of "tenement" houses; houses in courts, and "self-contained" houses. The rental varies from £300, to less than £2 per annum. Some particulars regarding the class of property in three of these districts are given in the following Table:—

Number of stopcocks.	Number of occupants at night.	Class of property.	Gallons per head per day. At starting of meters. Total.	At starting of meters. Night-rate per 24 hours.	After three first inspections. Total.	After three first inspections. Night-rate per 24 hours.
79	2,971	Good tenement houses £12 to £24 rental, with a few inferior tenement houses, £3 to £10 rental. About fifty shops about £30 to £100 rental	60.0	42.5	34.0	16.4
98	731	High-class property, chiefly self-contained houses, £80 to £300 rental, with a few tenement houses, £40 to £60 rental. No shops........................	146.4	152 7	60.0	48.2
42	1,562	Old property, chiefly low-class tenement houses, about £2 to £8 rental, with a few better houses about £8 to £16 rental. A few inferior shops, £6 to £22 rental....................	14.3	7.4	13.3	4.8

The proceedings carried out, when it was proposed to put a district under the meter system, were as follows:—

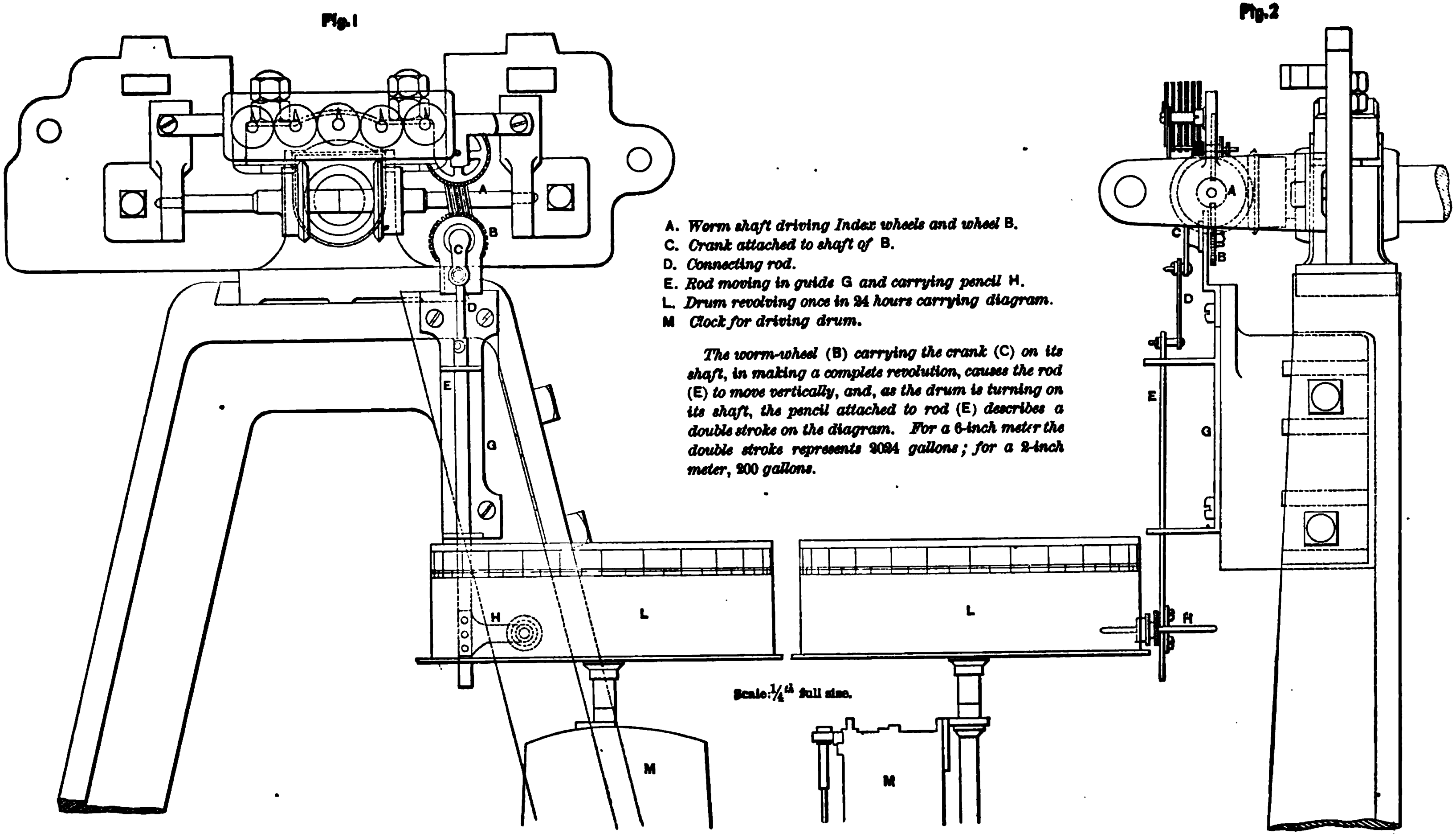
1. A sketch was prepared of the main piping as it existed.

2. The approximate number of families was ascertained in each district proposed to be included.

3. The district was divided into sub-districts containing such a population that, during the hours of greatest consumption of water, the limits of the meter diagram should not be exceeded.

4. Each district was arranged to include a population as nearly equal as possible. This was not carried very far, as it would have necessitated the laying of additional piping. The piping is in short lengths, except in sub-district II. 5, where it is in moderately long lengths. A 4-inch pipe is seldom laid within the city of a longer length than 150 yards, and supplies from 50 to one hundred and fifty families only. This arrangement is for a plentiful supply of water in case of fire. Had the piping been altered so that the populations in the meter districts should have been equal, the efficiency of the fire cocks would, in most of the districts, have been seriously interfered with, unless considerable lengths of additional piping had been put down to make new connections to the principal mains. The efficiency of the fire cocks was maintained, and the isolation of the sub-districts secured by connecting some of the distributing pipes to each other, and disconnecting others without strict regard to equalizing the populations.

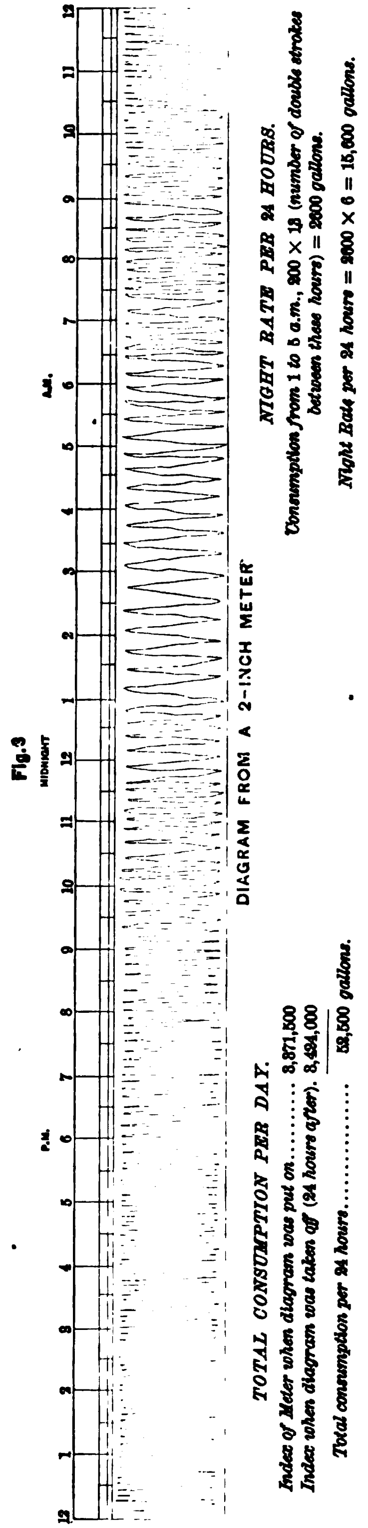
After the alterations in the piping had



A. *Worm shaft driving Index wheels and wheel* B.
C. *Crank attached to shaft of* B.
D. *Connecting rod.*
E. *Rod moving in guide* G *and carrying pencil* H.
L. *Drum revolving once in 24 hours carrying diagram.*
M *Clock for driving drum.*

The worm-wheel (B) *carrying the crank* (C) *on its shaft, in making a complete revolution, causes the rod* (E) *to move vertically, and, as the drum is turning on its shaft, the pencil attached to rod* (E) *describes a double stroke on the diagram. For a 6-inch meter the double stroke represents 2024 gallons; for a 2-inch meter, 200 gallons.*

DIAGRAM APPARATUS FOR A 6-INCH METER



been decided upon, drawings showing these and the position of the meter were sent to the workmen's department. While the meter was being placed in position and the alterations in the piping were being made, day inspectors took the census of the district. Other day inspectors ascertained the position and condition of every house stop cock in the district, and the premises which each supplied. As it was found in the first districts that the bad state of the stop-cock cases retarded the night inspectors in the subsequent ones, these received a thorough overhaul, large numbers being entirely rebuilt; in the experimental district there were 567 stop cocks; 343 of the cases on these were rebuilt, and 295 cast-iron boxes put on. In addition, considerable alterations had to be made on the lead pipes, to improve or simplify the supply to tenants.

When a district was isolated, and the meter put in working order, a few diagrams were taken to show the initial consumption, and thereafter a night inspection was made.

Night Inspection.—This is conducted as follows: The inspector puts a diagram paper on the meter a few hours before the night inspectors commence work. At midnight two inspectors begin to sound the stop cocks in the sub-district. When a noise is heard on applying the key to a stop stock, it indicates that water is passing. The inspector makes a note of this, and of the time of sounding. When no noise is heard with a stop cock full on, it is partly shut, and if water is passing the increased velocity always causes a distinct sound. Having sounded and shut all the stop cocks in the district, an interval of half an hour is allowed to elapse before opening them. The inspectors then write out a list of the stop cocks found sounding, and leave it at the office. From this a clerk prepares slips for the day inspectors. These examine the premises indicated through the sounding stop stock. The subsequent proceedings are the same as those which follow an ordinary house-to-house inspection.

At the commencement of the night inspections, much delay was caused by the bad state of the stop cock cases, but at present the district containing the largest number of stop cocks, viz., 102, can be examined by two inspectors in about three hours and a half.

If several adjacent stop cocks sound when shut, it proves that there is a waste on the street side of the stop cocks, or on a service pipe not shut off. The position in the former case may be determined by observing which stop cock gives out most sound when shut. If on shutting one stop cock the others give no sound on being re-sounded, the inspectors retain it in their books and mark out the others.

In a night inspection of sub-district III. 1, the rate of flow of water before the inspectors began was 1,500 gallons per hour; by shutting all the stop cocks this was reduced to zero. In an inspection of sub-district IV. 3, a flow of 2,000 gallons per hour was recorded before the inspectors began; by shutting the stop cocks this was reduced to 50 gallons. And in sub-district IX. 2, a rate of flow of 2,000 gallons per hour was, by the same means, reduced to 150 gallons per hour.

It frequently happens that the rate of of flow, for a short time after the stop cocks are opened, is higher than the average night rate for the same night. This is due to the water filling the leaky service pipes, &c., which have become partly empty while the stop cocks remained shut.

Diagrams.—Diagrams were taken off each new meter every day, until the district had been put into proper order and the consumption reduced as far as possible. Thereafter three diagrams were taken of each meter on three consecutive days in every twenty-eight days, the meters being visited in rotation; and this practice obtains at present. These diagrams afford a reliable average of the consumption during the month, and show which districts are most in need of a night inspection. The inspector brings the diagrams to the office during the day; they are calculated, and the results plotted in a diagram book.

The calculation of the diagrams is somewhat laborious. The night rate is more easily obtained than that of the day, and the result is more reliable. As a rule the most confused diagrams are obtained from districts in which a considerable quantity of water is used for trade purposes.

As the first group of sub-districts has been longer in operation than the others, and as it was an experimental district, more information has been collected regarding it. After a sufficient number of diagrams had been taken to show the initial consumption in each district, the night inspections were commenced and continued every alternate night in a new district. This brought the night inspectors round to the same district at the end of three weeks, which gave sufficient time for the repairs to be made. Each night inspection was followed by a day inspection. Since there were cases in which the number of families to one stop cock was as high as 27, the source of waste was not easily traced; in addition, a certain class of fittings was found to remain tight during the day, but at night, when the pressure was highest, the fittings opened and allowed a large quantity of water to escape. These caused many fruitless visits.

The number of fittings found out of repair in the nine districts was 2,629, and comprised the following: Ball cocks, 897; screw-down cocks, 606; common ground cocks, 279; Renison's cocks, 68; lead pipes, 96; other fittings, 92. Water-closets, 591. There was 72 per cent. of the kinds of fittings allowed by the regulations of that time; 28 per cent. were of the classes proscribed in October, 1875; 350 water closets of the kinds that allow waste were found. At that time they were not proscribed, but are so now. The lead service pipes were proscribed as they weighed only 7½ and 8 lbs. per yard instead of 10 lbs. Of the 96 burst pipes, 69 were discovered by the night inspectors below ground making no show on the surface.

The distributing pipes were, with one exception, found tight.

In three cases, upon the lead service pipes being repaired, the consumption in one of the sub-districts fell 15,000, 17,000 and 12,000 gallons respectively. A small part of this may be due to other repairs being carried out at the same time.

In the experimental district, at the starting of the meters, the average rate of consumption was 59.2 gallons per head per twenty-four hours, which was reduced at the lowest to 26.6 gallons; the corresponding night rates were 45.0 and 10.8 gallons.

The results obtained in this group of districts were made the subject of a report to the Water Works Commissioners by Mr. Gale, and the system was subsequently extended to other nine districts, which were divided into forty-one sub-districts. The population at present under control is 81,289 persons; the largest number of persons to one meter is 3,310, the smallest 642, and the average 1,626. In Appendix II. some statistics are given; from which it will be seen that the average number of families to one stop cock is 6.8, and that the average number of stop cocks to one sub-district is 53.

The forty-one additional sub-districts were treated in accordance with the practice that experience proved to be the best in the experimental district. At first the night inspections were made at intervals of three weeks, and, as before, these showed the best results; they are given in Appendix III. Afterwards the night inspections were made in each district at intervals of nine weeks, irrespective of the amount of waste going on in each, so that reliable data might be obtained of the effect of close watching, and which districts would require most attention. These inspections were also for the purpose of getting as many as possible of the proscribed fittings removed.

The fittings found out of repair and wasting water in these districts were much the same as those in the experimental district: lead pipes too light to stand the pressure or unprotected from frost, and a certain class of fittings which open at night under the increased pressure, being the most fruitful sources of waste.

Results.—That this system has been a success may be seen by reference to Appendix III., in which the average results for each group of districts are given: (1) At the starting of the meters; (2) after the first three inspections were completed; (3) on the 6th of January, 1881. It may be explained in regard to the last results that, on account of frost, they indicate a somewhat higher consumption than the average of the previous year. Appendix IV. gives the averages for the year 1880.

As the tables do not show the results obtained in any of the sub-districts, a few of the more striking are given here:

Number of Dist'ct.	At Starting of Meter.		After the 3 first Inspections.	
	Total.	Night rate per 24 hrs.	Total.	Night rate per 24 hrs.
	Gallons.	Gallons.	Gallons.	Gallons.
I. 2...	81.8	64.0	34.1	9.9
I. 3 ..	68.8	45.7	31.9	15.0
II. 2...	over 70.0	over 70.0	35.5	17.5
IV. 2...	41.6	27.4	27.4	8.3
IV. 6...	61.0	55.0	47.2	23.8

In seventeen districts at the starting of the meters the consumption per head per twenty-four hours was 60 gallons or more; in eleven of these it was reduced by the three first inspections below 40 gallons. In twenty-five districts at the starting of the meters the night rate per twenty-four hours exceeded 40 gallons; it was reduced below 20 gallons by the first three inspections.

Appendix III. shows that at the starting of the meters the average consumption for all purposes was 49 gallons per head per twenty-four hours, which was reduced to 33 gallons by the first three inspections; the corresponding night rates were 37.7 and 17.5 gallons. The night rates, however, are exaggerated, on account of the pressure being much higher at night than during the day. On the 6th of January, 1881, the consumption was 35.3 gallons, which shows a saving of 13.7 gallons per head, or if the whole district under control be considered the saving is 1,114,317 gallons per twenty-four hours, equal to 1.48 gallons per head of the whole population in the area of supply. If a saving of 13.7 gallons per head was made over the whole of Glasgow and district, containing 754,778 persons, the total saving would be 10,340,450 gallons per twenty-four hours.

The operations showed almost uniformly that the quantity of water consumed increased during the nine weeks which elapsed between two inspections, and the most reliable observations gave an increase of 3.4 gallons per head on an average. The total saving per head after the first three inspections were completed was 17 gallons, so that if the consumption continued to increase at the rate of 3.4 gallons in nine weeks, the original rate of consumption would be reached in ten months and a half. In some of the districts the increase was at the rate of only 2 gallons in nine weeks; in others it was at the rate of 7 gallons.

An instance of the gradual increase in the rate of consumption may be referred to in sub-district IV. 3, when left without inspection for three months and a half. Before the night inspection the consumption per head per twenty-four hours was 27.0 gallons, and the night rate 15.3 gallons. Fourteen days after the inspection had been made the rates were 22.2 and 10.1 gallons; six weeks after the inspection the rates were 23.3 and 9.6 gallons; ten weeks after the inspection the rates were 26.5 and 12.6 gallons; and fourteen weeks after they had increased to 28.0 and 14.9 gallons.

Cost.—The cost of the operations connected with the fifty districts was as follows:

	Total cost.			Cost per District.			Cost per 1,000 persons.		
	£.	s.	d.	£	s.	d.	£	s.	d.
Fix'g meters and altering pipes.	1,882	17	11	37	13	2	23	0	1
Repairing service stopcocks.	1,062	16	5	21	5	2	12	19	9
	2,945	14	4	58	18	4	35	19	10
Meters.........	1,372	2	2	27	8	10	16	15	3
Totals.....	4,317	16	6	86	7	2	52	15	1

The average cost of the first three inspections of each district was £12 14s. 5d., and the average cost of each of the inspections made at intervals of nine weeks, was £3 5s. 11d.

The saving of water on the 6th of January, 1881, was shown to be 1,114,317 gallons per twenty-four hours. At the cost price of the water, 20s. per 100,000 gallons, this amounts to £11 2s. 10d. per day, and as the expense is about £1 13s. per day, the daily net saving is £9 19s. 10d.

At present the attention of the night inspectors is devoted to the districts where the waste is greatest. An inspection is made on six nights in the week, each time in a new district. A day inspection follows each night inspection. Three diagrams are taken off each meter every four weeks to ascertain the consumption in the district, and in addition a diagram is taken off at each night inspection. To perform these duties one meter inspector, two night inspectors, and from two to three day inspectors are required.

The above are the principal facts regarding the system of district meters as carried out in Glasgow. It has been introduced since into London, Hull, Blackburn, Carlisle, Exeter, and other towns in England. The practice followed in these towns differs considerably from that followed in Glasgow, and as the application of the system has not been so extensive, the information regarding the sources of much of the waste has been correspondingly less. As showing the differences which obtain in applying the system to most of these towns, Carlisle and Blackburn have been selected as fairly representative of the others.

The system was introduced in Carlisle in 1876. At present there are five meters in use, controlling a population of 16,000, being an average of 3,200 persons to each meter. In a letter to the author, Mr. J. Hepworth, Assoc. M. Inst. C.E., states that the "consumption in one of the districts was 52 gallons per head of population when the meter was put in, and it was afterwards reduced to 21 gallons in consequence." Over the whole population under control of the meters, namely 16,000, the average consumption of water for all purposes was 42 gallons per head per day at the time of starting the meters; the effect of the inspections was to reduce the consumption to 21 gallons.

About once a month an inspection is made of the districts commanded by the meters. All the stop cocks are shut, so that if the meter continues to register more water than can be accounted for by small quantities passing through the stop cocks, the mains or service pipes are probably leaking and are thereupon examined.

The meters used are waste-water meters. They were introduced by Mr. Hepworth because of the old service mains and pipes being worn out, and causing an enormous waste of water, which, although well known to exist, could not be discovered. Mr. Hepworth stated in his report to the water committee of Carlisle, in August, 1879, that by means of the meters 232 leakages had been discovered in the pipes during the past year, and 812 in the domestic fittings. By means of the meters and by the gradual renewal of defective mains, service pipes and fittings, the supply which had previously been precarious, has been converted into an abundant one.

About fifteen months ago, six of Deacon's waste-water meters were put on as many districts in Blackburn, containing an aggregate population exceeding 20,000 persons.

The population of each district has not been ascertained, so that the saving per head has not been arrived at. But the extent and locality of the waste is determined by shutting the service cocks at night. If the meter continues to register more than can be accounted for by water passing through some of the defective stop cocks, the service mains are tested. On water fittings and service pipes being found defective the owners are called upon to repair them. When a sufficient time has been allowed for the repair of these a diagram is taken from the meter and compared with the one obtained before the inspection.

The night inspections are made at irregular intervals about once a week. In district No. 5, at one of the night inspections, 600 gallons of water per hour were found passing; an inspection made three days afterwards showed 4,500 gallons; on the leak which caused this being repaired, the rate was reduced to 1,200 gallons, and subsequently to 500 gallons per hour.

The table on next column, prepared by Mr. W. B. Bryan, M. Inst. C.E., shows the class of property in each district and the results of the night inspections.

Number of District.	Class of Property in District.	Consumption of Water per hour in night.	
		At starting of Meter.	Best results after Meter was fixed.
		Gallons.	Gallons.
1	Cottage property entirely........	530	400
2	Cottages principally; a few mills, &c... ..	4,600	800
3	Houses and shops in center of town	2,709	600
4	Houses, cottages, shops and a few mills...........	3,500	750
5	Houses, cottages, shops and a few mills...........	1,000	500
6	Houses, cottages, shops and a few mills...........	1,200	700
	Totals........	13,530	3,750

Thus at the best there was a saving of 9,780 gallons per hour, or 72 per cent.

(3) *Prevention of waste by means of Pressure-reducing Valves.*—The object of pressure-reducing valves is to maintain a constant pressure in the distributing pipes, while the pressure in the mains may increase. It has been ascertained that the waste from defective pipes and fittings is much greater during the night than during the day on account of the increased pressure; to reduce this, and thereby relieve the fittings, &c., various forms of pressure-reducing valves have been applied. The older forms were worked by weights applied directly to the valve, or by means of a lever; and as the pressure applied required to be equal to the difference of pressures on the opposite sides of the valve, these valves could only be applied to small pipes. Recently valves capable of being controlled by small power have been coming into use. Of these the Foulis Pressure Reducing Valve is a good example. It is similar in action to that of gas governors. An account of the various modifications of this valve, and an explanation of the action, was given by Mr. Stephen Allen, at the Glasgow meeting of the Institution of Mechanical Engineers.*

Application of the valve.—At Glasgow, in October, 1879, the valve was applied to a district commanded by a waste-water meter, and afterwards to a second. In both districts the ordinary variations of pressure in the mains is from 40 lbs. per square inch during the day to 85 lbs. at night. The valve was, in the first district to which it was applied, adjusted so that the pressure on the outlet should not at any time exceed 45 lbs. per square inch. From 4 P.M. on the day it was used to 8 A.M. on the following day the saving of water was shown by the meter diagram to be 12,600 gallons. The saving appeared to begin at 4 P.M., to go on increasing till midnight, remaining stationary till 5 A.M., and terminating at 8

* *Vide* Institution of Mechanical Engineers. Proceedings 1879, p. 427.

A.M. The population in this district was 2,971, so that the saving was 4½ gallons per head per day. The night rates per head per twenty-four hours before and after the valve was fixed, were:—

	Gallons.
Average rate per head per twenty-four hours before valve was applied	24.7
Ditto, after valve was applied	15.0
Saving	9.7

The second district to which the valve was applied contained a population of 2,381. The valve in this instance was adjusted so that the pressure on the outlet should not exceed 40 lbs. on the square inch. As before, the saving began about 4 P.M. and terminated about 8 A.M. The following shows the saving effected:—

	Gallons.
Average rate per head per day from the 1st of November to the 15th of November, 1879	36.2
Valve adjusted on the 17th of November.	
Average rate per head per day from the 19th of November to the 3rd of December	28.0
Saving	8.2

The saving effected in the night rates corresponding to these was 10.8 gallons per head per twenty-four hours.

A valve similar in character to that used in Glasgow, was fitted up in Cambuslang, a village near Glasgow. Mr. W. R. Copland, M. Inst. C.E., furnishes the following particulars regarding its performance:—"This valve was fitted up about March, 1879, at a junction of a branch with the main pipe. The distributing reservoir is about 160 feet above the houses supplied through the valve, which are chiefly of the tenement class, with very inferior fittings. The main is 4 inches, the branch 3 inches in diameter; the undisturbed pressure in the main would be about 70 lbs.; and the governor is set to 30 lbs. pressure per square inch. The consumption has been taken for about a week before the governor was fitted, and it was found that to lower the level in the distributing reservoir by 6½ feet required on an average four hours and forty minutes. After the governor was fitted the experiment was repeated, and it was found that the time required averaged seven and a quarter hours, showing a saving of 35 per cent. The experiment has been several times since repeated with the same results."

Four of the reducing valves known as the "differential reducing valves," have been for some time in use in Busby, a village near Glasgow. The peculiarity in these is that the piston is of less area than the valve, and by making them of different ratios any desired pressure may be taken off; but once fixed the ratio between the outlet and the inlet pressure cannot be changed. As the pressure is too high in the village of Busby, cisterns were at first employed to reduce it, but these have been replaced by differential reducing valves. The sizes of the valves, and the extent to which each reduces the pressure, are as follow:—

8-inch valve; reduces pressure from	100	to	90 ft
6 " " " " "	194	"	94 "
6 " " " " "	70	"	10 "
5 " " " " "	160	"	110 "

The levels of some of the houses near the valves and supplied from the outlet side have been taken, and from these it is found that the valves perform the required reductions in pressure with great exactitude.

CONCLUSION.

The various methods adopted for the prevention of waste of water have proved that by far the largest proportion of waste is due to imperfect and defective fittings and service pipes, and that when for these, proper apparatus has been substituted, the waste has, in many cases, been reduced by more than one half. It has been shown that the worst classes of fittings are common ground cocks, ground ball cocks to cisterns, and water closets supplied by taps. If waste is to be prevented, screw-down cocks and "waste preventing" apparatus to cisterns must be substituted; in no case should water closets be supplied by taps. No matter what system may be employed for the detection and prevention of waste, it will be of little use if it does not embrace the removal of all defective fittings. And for securing that new fittings shall be perfect in design and workmanship, evidence appears to show that the method of keeping samples and testing and stamping is that which best meets the exigencies of the case.

Each of the three systems for detecting and preventing waste, namely, house-to-house inspection, district meters, and reducing valves, has its special uses and applications. None of them is perfect, but each becomes more nearly so on being combined with one of the other two. Taking each in order:—

(1) House-to-house inspection, combined with the practice of removing defective fittings, has been proved sufficient to reduce waste to its lowest limits, but at an expenditure of energy and money which few towns can afford. It fails to detect obscure cases of waste, such as occur underground and are continuous. In carrying it out the conscientious tenant, who takes care of his fittings, receives as much annoyance as a careless one, who allows his fittings to waste water. The system entails no check on the inspectors, and it affords no evidence as to how far their operations are a success.

(2) District meters show where most waste takes place, the locality of a leak, and the saving of water effected. The night inspections which, however, might be carried on in connection with any other system, are made at the most favorable time for the discovery of waste. As the day inspectors visit those premises only where water was found passing on the previous night, conscientious tenants receive no trouble, while careless ones receive an extra amount. In Liverpool the inspection entails visits to only one-tenth of the people that house-to-house inspection would involve. In Glasgow the proportion is about one-fifth. Add to these facts the amount of time saved, and the certainty of knowing whether the inspectors do their duty or not, and the benefits of the system are evident.

(3) Pressure-reducing valves appear to deserve more attention than they have yet received. By reducing the pressure in the lower parts of a town an increase may be made to that in the higher parts, where it is usually most required. In low-class districts, where wells are most frequent, a head pressure of a few feet is all that is required; where cottage houses, or where "tenement houses" exist, a higher pressure is needed, and for regulating the pressure to the various wants of a town the pressure-reducing valve seems eminently suitable. In all cases it relieves the fittings of pressure, and thereby removes much of the waste due to them. If the water is extensively used for power in a town, reducing valves cannot be adopted to the same extent, as they interfere with the working of the hydraulic engines. In considering meters and reducing valves it is necessary to bear in mind that the former do not prevent waste, they simply point out where it exists; the latter prevent waste but do not detect it.

In comparing the results obtained in the various towns by any system, regard must be had to the different conditions of supply which obtain; the proportion of taps, baths, water closets, and the like; the regulations as to the removal of the defective fittings, and to the difference in mode of living of the people. More especially is this the case in comparing the results obtained in Glasgow by the district-meter system with those obtained in Liverpool or elsewhere. The supply of water to Liverpool was exhausted; a new supply could not be introduced in time to ward off a dearth of water, and the Corporation were unable to procure an Act of Parliament giving them proper control over the consumers' fittings. In such circumstances Mr. Deacon applied his meter, and succeeded in so far reducing the waste that the town was restored to a state of plenty. In Glasgow the meters were started under no such conditions; the supply is in excess of the demand, and so long as this continues there is not the same necessity for expending time and money in enforcing strict economy. House-to-house inspection being in force prevents flagrant waste, and has prevented the consumption of water per head from increasing for several years. Besides house-to-house inspection, the method of testing and stamping all fittings will gradually secure fittings of first-class design and construction, and these of themselves will go far in reducing the waste. In no other town in the country having a constant water supply is there so large a proportion of fittings to the population, and as baths and water closets require a large quantity of water, there is no likelihood that the rate of consumption will be reduced to the same point which obtains in towns not so well off for water supply.

In estimating the various methods for preventing waste, regard is had to the expense, and as this is the only matter on which corporations and water companies venture to decide what shall be done, it is natural that at first they should select that which appears least expensive. Owing to house-to-house inspection sometimes giving good results it is usually preferred, but the degrees of success which attend it are extremely various, and in no case can it be effective unless stringently carried out.

APPENDIX I.

Proscribed Fittings, Glasgow.

I. *Water closets.*—1. Lambert's cottage valve; 2. Mitchell's valve; 3. Ross' valves; 4. All kinds of cocks.

II. *Taps.*—1. Common ground cocks; 2. Renison's cocks; when these taps are supplied direct off the main.

III. *Taps on stairs and in courts*, when not self-closing.

IV. *Worn-out fittings.*—Any apparatus, when the inspector is of opinion that it is so far worn out that no permanent repair can be made.

APPENDIX II.—District Meters, Glasgow.

Number of Stop Cocks, Families, and Occupiers.

Number of district.	Number of sub-districts.	Number of stop cocks.	Number of families.	Number of families to one stop cock.	Number of occupiers at night.	Number of persons to one family.
I.	9	580	3,212	5.5	14,972	4.7
II.	6	447	2,012	4.5	10,002	4.9
III.	3	141	1,138	8.1	4,986	4.4
IV.	6	249	1,682	6.8	7,629	4.6
V.	7	260	2,294	8.8	9,815	4.3
VI.	8	318	2,998	9.4	12,614	4.2
VII.	2	162	886	5.5	4,182	4.7
VIII.	3	170	1,267	7.4	6.306	5.0
IX.	4	244	1,768	7.2	7,821	4.1
X.	2	87	708	8.1	3,012	4.2
Totals......	50	2,658	17,965	—	81,289	—
Averages....	—	53	359	6.8	1,626	4.5

APPENDIX III.—District Meters, Glasgow.

Abstract Showing Consumption and Results of Inspection.

The quantities include all meter and trade supplies.

Number of district.	Number of sub-districts.	Number of occupants at night.	Gallons per head per day.					
			At starting of meters.		After three first inspections.		At 6th January, 1881.	
			Total	Night-rate per 24 hours.	Total	Night-rate per 24 hours.	Total	Night-rate per 24 hours.
I.	9	14,972	59.2	45.0	34.1	17.6	38.6	22.7
II.	6	10,002	65.8	60.2	42.0	27.5	44.8	28.8
III.	3	4,986	61.4	52.0	36.8	18.1	42.3	22.8
IV.	6	7,629	65.8	47.5	42.1	20.7	44.7	27.9
V.	7	9,815	45.9	30.7	31.4	14.4	29.7	15.6
VI.	8	12,614	31.0	24.6	22.6	14.8	29.1	21.9
VII.	2	4,182	37.9	25.5	34.9	21.5	31.3	20.1
VIII.	3	6,306	37 4	22.9	28.0	12.6	28.7	16.0
IX.	4	7,821	37.4	26.4	25.7	12.7	27.8	17.2
X.	2	3,012	36.8	27.8	20.8	10.7	34.5	24.3
Totals and averages	50	81,289	49 0	37.7	32.0	17.5	35.3	21.9

APPENDIX IV.—District Meters, Glasgow.

Abstract of Results of System of Night Inspection for the Year 1880.

Number of district.	Number of sub-districts.	Number of occupants at night.	Gallons of water per head per day. At starting of meters.		At Jan. 8.		At Feb. 5.		At March 4.		At April 1.		At May 18.		At June 10.		At July 8.		At Aug. 5.		At Sept. 2.		At Oct. 14.		At Nov. 11.		At Dec. 9.	
			Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night rate per 24 hours.
I.	9	14,972	59.2	45.0	36.7	23.4	37.0	23.8	38.1	25.5	41.9	20.0	38.3	22.1	40.1	18.7	39.8	19.4	39.5	20.2	42.2	21.6	42.2	20.4	35.4	21.8	41.2	25.0
II.	6	10,002	65.8	60.2	44.1	30.9	40.8	24.7	36.9	21.9	37.4	23.1	38.6	21.9	33.8	20.0	33.9	20.4	35.2	21.5	37.1	21.8	40.1	23.1	40.8	26 2	43.5	27.9
III.	3	4,986	61.4	52.0	39.6	21.5	35.4	21.8	35.2	26.7	40.8	24.1	39.7	25.4	39.7	23.5	39.7	22.7	41.9	18.6	40.0	16.8	33.7	17.3	38.6	19.6	42.0	22.7
IV.	6	7,629	65.8	47.5	42.8	26.8	36.7	22.5	37.2	18.9	38.9	19.5	34.0	20.0	44.0	27.4	46.1	24.7	42.1	27.1	52.8	25.5	45.8	27.0	45.1	25.3	45.3	27.3
V.	7	9,815	45.9	30.7	29.8	15.6	29.6	16.7	30.1	15.5	35.4	19.8	31.0	13.8	33.6	15.7	35.4	16.9	33.7	14.1	36.1	15.8	36.0	16.6	36.9	20.6	32.7	16.8
VI.	8	12,614	31.0	24.6	27.9	20.1	29.0	23.3	31.9	24.3	29.0	19.8	27.8	16.5	29.2	17.1	28.2	16.8	29.5	16.9	28.4	15.9	31.6	17.4	27.3	17.0	31.2	23.0
VII	2	4,132	37.9	25.5	31.4	21.1	32.2	24.2	33.9	24.7	30.6	17.7	31.2	17.3	31.0	17.8	29.7	21.2	32.9	21.2	28.4	22.1	35.3	19.5	32.6	21.5	37.1	26.5
VIII.	3	6,306	37 4	22.9	24 7	12.9	26.7	17.3	28.5	14.7	27.2	14.7	29.1	16.5	30.8	16.3	28.1	13.9	30.5	14.6	32.5	18.8	32.6	18.1	29.8	17.4	31.2	17.8
IX.	4	7,821	37.4	26.4	28.0	15.2	29.4	20.1	33.3	22.5	31.6	19.7	31 4	19.2	34.9	19.0	32.0	16.5	36.0	20.3	33.3	16.2	34.9	18.4	30.7	18.2	31.4	20.0
X.	2	3,012	36.8	27.8	28.2	16.3	28.4	21.5	24.0	15.4	28.4	18.2	30.1	19.0	32.5	16.3	31.0	17.0	38.7	24.4	35.2	18.9	34 2	19.5	30.5	18.5	28.2	16.1
	50	81,289	49.0	37.7	34.5	20.9	32.9	21.6	33.5	21.6	34 2	19.8	33.2	19.1	35.1	19 1	34.3	18.8	35.4	19.5	37.1	19.3	36.9	19 8	34.9	20.8	36.8	22.8

THE SOIL AND ITS INFLUENCE ON HUMAN HEALTH.

From "The Builder."

At the recent meeting of the German Society of Natural Philosophers and Physicians at Saltzburg, the eminent Dr. Pettenkofer read a valuable paper on the subject of the influence of the soil upon human health. The subject, he said, was one of the oldest in sanitary science, but it possessed of necessity a permanent interest, as it was constantly presenting itself under new aspects. The soil, the air, and the water had been from time immemorial regarded as the principal factors in the problem of the salubrity of localities. It was these which made a place healthy or the reverse. In recent times there had, in Dr. Pettenkofer's opinion, been a tendency to look too exclusively to the air and water, and to neglect the influence of the soil in sanitary questions. But the ground on which men built their houses, and on which they passed their lives, must always take a pre-eminent place in the determination of all sanitary problems. Dr. Pettenkofer pointed out that air is almost invariably in motion. The average speed at which it moves over the ground at the earth's surface is about 10 ft. per second. Even in a so-called calm, the air is not still; it is still moving at the rate of about 1ft. 6in. per second. Hence, even in abysses, and the most secluded valleys of the country, or the narrowest lanes of cities, the air is never really stagnant. Nearly the same may be said with regard to water. All water as it falls from the clouds is of nearly homogeneous composition. It is but very slightly impure. From the soil, however, water, like air, takes up certain impurities. These are generally removed from the air much more quickly than from the water. The circulation of water and its purification from foreign elements are more complicated and less expeditious matters than in the case of air. Nevertheless the process of purifying water goes on even in the drains and sewers of cities, but more especially in the great natural drains, the rivers,—like the Isar, at Munich; the Elbe, at Dresden and Hamburg; the Thames, at Oxford and London; or the Seine, at Paris and Rouen. It was in the soil that impurities were most obstinately and longest retained. The influence of the soil showed itself most clearly in the case of epidemic diseases. Malaria has always been recognized as dependent on the soil of the localities where it is found. But it was not less true that cholera, typhus fever, yellow fever, perhaps even the plague itself, likewise depended on, or were connected with, the condition of the soil. What we have still to settle is the question, "How?" It has been attempted to explain the epidemic appearance of such diseases by assuming that they were propagated through the air or water, or both. But it is incorrect to regard either air or water as the true cause of epidemics. This is generally to be found in the soil. One proof of this Dr. Pettenkofer found in the fact that ships at sea were inaccessible to cholera. It had been observed that when persons were attacked by cholera on the high seas, only those who came from the same localities caught the disease, while the other passengers escaped. It was only exceptionally that the epidemic broke out on board a vessel, and then only when the passengers and crew were in frequent contact with an infected locality on shore. But even on land there were places safe against epidemics. Thus, Lyons, in the south of France, in spite of its large traffic with Paris and Marseilles, where cholera was raging, remained free from the disease. The only explanation that could be found was the condition of the soil or ground at the former city. Still more surprising was the immunity of Versailles from cholera, when Paris, with which it was in constant and immediate communication, was the scene of an outbreak of that epidemic. The investigations of the German Commission on Cholera have clearly shown that epidemics are localized, and that they are caused by the condition of the soil.

What is that, asked Dr. Pettenkofer, in the condition of the soil which is able to produce such an effect upon the health? He answered that probably it would be found in a vast number of minute infinitesimal organisms,—so minute that millions of them might, if collected, lie on the head of a pin. Dr. Nageli has distinguished such organisms, and presented a faithful and vivid picture of them as they rise from time to time out of the ground. He makes a distinction between soil that is pestilential or unhealthy, and soil that is healthy or free from pestilence. This distinction does not coincide with the presence or absence of a certain kind of fungus, as this is found growing everywhere. However, if the disease is attributable to the same species of fungus generally found growing in every place, then the same forms of these little organisms must produce different effects under different circumstances. It is the task of hygienic science to examine the conditions of the soil favorable to the development of these organisms and their entrance into the human system. It has long been known that by means of drainage and cultivation or tillage an injurious unhealthy soil, like that of the malaria districts, may be deprived of its dangerous character. Even in ancient times canals were cut by the Romans in order, by drainage, to reduce the evil effects of the malaria, though these works had subsequently been destroyed and forgotten. Certain diseases have their favorite haunts in alluvial soil on account of the porous nature of that soil. The spaces and interstices of this soil favor the circulation of air and water. But the same may, to a certain extent, be said of some kinds of porous rock, as is proved by the appearance of cholera in rocky places like Malta. Exact investigation respecting the air in soils have shown its importance from a sanitary point of view. On thoroughly dry soils the ground air does not absorb any more carbonic acid or organic matter than the air above the ground. This has been shown by experiments with the air brought by Dr. Zittel from the Libyan Desert. The subterraneous or underground air circulates in the soil, although but slowly. During the greater part of the year it penetrates into badly-built dwellings, and conveys them into the fungous germs of disease. In this manner the soil influences human health, and there are only too many dwellings subject to this influence, which is the more baneful the worse they are ventilated. Our houses, in fact, draw or suck the air out of the ground like so many cupping glasses. From a hygienic point of view they are, indeed, less rational than the old pine dwellings of primeval humanity, or than even the village cottages of the present day, whose floors are covered with mud plaster. This was illustrated in the case of an outbreak of cholera at Dantzic, where out of a group of nine cottages, seven modern-built ones, with cellars and plank floors, were visited by the epidemic, while the only two with mud plaster escaped. Accordingly, it appears that in our houses we must pay more attention to the soil on which they are built. Such arrangements should be made in their construction that we should no longer be compelled to take to flight when an epidemic breaks out. A proper method of sanitary construction would enable us to withstand successfully a siege, so to speak, by the cholera, in which case it could be said with greater truth than ever that "a man's house is his castle," Dr. Pettenkofer regards it as the duty of Governments to take the initiative in this matter. Not less important than the air is the water. All organisms require moisture. There are two degrees of moisture to be distinguished: first, that in which the pores of the soil are occupied by air and water in common; and, secondly, that in which the water has entirely driven out the air. In the first case, we have a damp soil; in the second, we have underground water. The intimate connection between typhoidal diseases and the underground water has been long recognized. When underground water rises higher than the average, typhus disappears, but when again the water in question sinks below its average level, typhus increases. This had been shown clearly by observations made in Berlin. Any apparent exceptions such as places visited by typhus, though without underground water, yet having a porous soil, or again the unimportance of the level of underground water near rivers, did not invalidate the argument. As, amongst us in Europe, the abdominal typhus fever depends on the rainfall and the level of the underground water, so in India does the cholera depend precisely upon the like causes.

With regard to the theory attributing cholera, typhus, and all zymotic diseases mainly to the water we drink, Dr. Pettenkofer advanced some arguments against its unconditional acceptance. The malaria poison, for instance, does not enter the water. The *baccillus malariæ* has been proved to be an organism living in the air, not in the water, of the infected districts, and it was from the air that they penetrated into the human system, and ultimately into the blood. The real cholera germ has not yet been accurately ascertained or identified. It is still doubtful whether it is disseminated more by water than by air. The drinking water of places visited by cholera has often been entirely given up without preventing the re-appearance or continuance of the epidemic. The city of Basle, for instance, possesses the purest drinking water which is brought down from the Jura, but has not been protected by it from the disease. Dr. Pettenkofer, however, would not question the importance of the water we drink, in regard to this question. Far from denying the value of good waterworks, the speaker dwelt on the importance of pure drinking water. The *bacteria* question, too, was one of the highest importance, but the theoretical deductions on that subject required to be practically employed and confirmed by practical experiments. To the observations of a Pasteur there needed to be added the practical applications of a Lister, in order to make them of value in sanitary or surgical science, and in the same way mykological investigations would require to be completed by hygienic researches. It had been observed that in the case of very concentrated and very diluted fluids used as nutriment, the very small organisms usually found in those fluids in their normal condition are destroyed. An inference drawn from this, that dirt is no danger to health, provided it be only thoroughly concentrated dirt, could not be admitted. In villages the dirt is not stronger or more genuine dirt than in towns. In the latter it is only covered up more, and, therefore, the more dangerous. In villages, too, the more cleanly dwellings were the healthier. But granting that concentrated dirt may hinder fungous vegetation, there still remains for hygienic science the task of ascertaining what must be the proper degree of this concentration, and to consider the conditions favorable to the injurious vegetation in question. Sanitary science was, in fact, one unceasing battle against dirt. As the growth of these minute fungi is increased by moisture, it might be thought that all would be right if everything were kept from the damp. However, we are not able to prevent everything from becoming damp or to prevent the dissemination of germs in a thousand different ways. It is in any case good to avoid or to draw off moisture. Dr. Pettenkofer strongly condemned the use of ground reservoirs for rain water and other such pits, as they contribute to keep the soil thoroughly moist, and are thus very injurious in the neighborhood of dwelling-houses. They serve, in fact, precisely like a sort of artificial inundation.

The doing away with the moisture or dampness of soils, or at least the dimimution of damp, is the main advantage of the various systems of drainage. The value of drains might be exaggerated, but we must beware of under-estimating them. Statistics prove that every city which has laid down a system of drainage has greatly benefited thereby. Further, Dr. Pettenkofer referred to the self cleansing process going on in the soil through the agency of certain very low organisms. The formation of saltpeter through certain fungous growths, shows that these minutiæ are capable of acting not only injuriously, but also beneficially. Hygienic science, at the present moment, stands in view of a practically boundless world of possibilities. But this must not discourage us from action. Hitherto, hygienic science has been guided chiefly by feeling, instinct, and so-called common sense; it is only recently that it has been established on a scientific basis. Cleanliness plays in public life an important part. Cleanly persons live longer and more healthy than the dirty. We ought to respect the sanitary system in common use, even though it still lacks a scientific foundation. But scientific criticism is necessary to refute false ideas, and to get rid of what is superfluous and hurtful. In conclusion, the speaker said that the advancement of sanitary and hygienic science, both in theory and practice, was one of the most important duties of the State.

THEORY FOR TURBINE WATER WHEELS.

By GUSTAF ATTERBERG.

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I.

In Sweden I often have been employed about the construction of turbine water wheels, but have never been satisfied with the theories for these motors; therefore I have now tried to make a more practical one. Since there are a great number of theories for these motors, there is no need of giving the derivations of the equations, unless they differ from those used by other authors. I have thus tried to make the treatise as short as possible and at the same time practical.

I know it has often happened, that turbines have been made for the most economical use of the water, but, when made and tried, they did not give so much power as was expected, and sometimes they gave very low efficiency, although the theoretical conditions for the best efficiency seemed to be correct. Then they thought that the friction between the water and the wheel was greater than they at first supposed it to be, although the assumed value for this friction was perhaps very high; and in order to obtain good efficiency they often gave the vanes a finished surface, but even then they did not obtain the gain expected. Then many thought that turbines could not give good efficiency or that the theories were not practical.

That several turbines gave more efficiency than usual happened only by change, as the theories used for them were more or less wrong, which everybody can easily see by looking at the theory which now will be published.

The conditions, which ought to be satisfied in order to obtain good efficiency, will now be mentioned in connection with some discussions of the motion of the water in the turbines.

The loss of efficiency, by the friction of the water, is of such a value, that it may be neglected, unless the distance between the vanes is too small or the relative velocity of the wheel is too great, which two cases never occur in practice. The distance through the wheel is very unimportant, compared with the head of the water, and therefore this loss of efficiency cannot have so great a value, as it it supposed to have. The motive for assuming so great a value for this loss of efficiency is, in my opinion, to be found in other neglected losses, and from wrong theories.

The space between the guide case and the wheel causes no, or very unimportant, loss of water; because the water passes through the wheel with great velocity, and in consequence with a great momentum. When it passes by this space the internal pressure (p_1) of the water tends to deflect its course through the opening; but in the short time required to traverse this distance, it cannot perceptibly change its direction, and it passes by the space and cannot pass through. The volume of water, that perhaps can come through this space, is unimportant in comparison with the volume that passes through the wheel. The wheels can thus be calculated without consideration of this loss. Should the pressure in the water be lower than the pressure of the atmosphere, according to the same reasoning, no air can come in through the space, if the width at the inlet of the wheel is some less than the width at the outlet of the guide case.

The normal velocity of the water, at the inlet of the wheel, ought to be the first consideration for the further calculation of the wheels; because on its value depends the dimensions of the wheels at the inlets and also the efficiency of the wheels. The less this velocity is the higher efficiency one can get; but this velocity cannot be very low, because the wheels then become of impracticable dimensions.

The vanes in the wheel ought to have the least possible thickness. Since the water has a great velocity it cannot instantly change its direction, and in consequence, when the water is obstructed by the vanes an impact by the water must be produced. Even if the edges of the vanes are very thin this impact may occur, and if it should not occur, a loss of efficiency would arise; because the water would take a partial motion in both directions from the vanes, according to their thickness, and a part of the natural power must be used to produce those motions. The maximum of this loss of efficiency is:

$$(1-\xi_1).\left(\frac{c_1}{c}\right)^2.\sin^2\alpha$$

when ξ_1 is a value that indicates what part of the inlet of the wheel the openings take, according to the thickness of the vanes, c_1 is the velocity of the water when it flows out from the guide case, c is the velocity which a body obtains by falling a distance equal to the whole head of the water, and α is the angle between the guides and the periphery of the wheel. The loss is expressed in proportion to the natural power. Set the value:

$$\frac{c_1}{c}=\sqrt{\mu}$$

then μ indicates, what part of the head of the water is used in order to give the water the velocity c_1 between the guides. The value of the loss is then:

$$(1-\xi_1).\mu\sin^2\alpha \quad . \quad . \quad . \quad . \quad . \quad (1).$$

The value of this loss depends only upon the judgment of the designer and is accordingly not taken into further account.

The water ought to flow through the wheel with a continually diminishing velocity, in such a manner as if there were an immense number of vanes. Such a flow of the water can be obtained by use of only a few vanes, if they are constructed in the manner shown in the following pages. Turbines ought not to be so constructed that the openings between the vanes will not become completely filled with water, because in such a case irregular motions in the water would occur. Then the wheels ought not to be called turbines, but only water wheels.

The width at the outlet of the wheel ought not to be too large, because the water perhaps cannot then obtain such a motion as required, and also perhaps cannot completely fill the openings between the vanes. If the width at the outlet of the wheel is larger than at the inlet, then the velocity (c_2) with which the water leaves the wheel diminishes, but the velocity with which the water spread increases. These two velocities make only losses of efficiency, and their sum ought to be as little as possible.

The water cannot spread in the wheel without a power to cause this spread, and unless impact and irregular motions occur, there is only one cause for the spread of the water, namely, the internal pressure of the water. This pressure depends upon the fact that the water flows between the guides with a velocity less than the velocity which corresponds to the whole head of the water, and also from the height between the upper surface of the water and the inlet of the wheel. If this internal pressure (p_1), is less than the pressure of the atmosphere, then ought the width at the inlet of the wheel be a trifle less than the width at the outlet of the guide case, in order to prevent the air coming in through the space between the guide case and the wheel. In the other case the pressure of the atmosphere will counteract the internal pressure of the water. The less this internal pressure is the less ought the difference between the widths at the inlet and at the outlet to be.

When the water flows through the wheel the value of the velocity with which it spreads ought to have a gradually increased value.

The Spread of the Water in a Turbine Wheel.—Fig. 1 is obtained by passing a plane, with its rectilinear elements parallel to the axis of the wheel, through the path which a particle of water would describe in passing through a radial turbine wheel, and developing the surface thus obtained. The line gh thus represents the length of the path, one particle moving in the center line of the cross section of the wheel describes. Such a shape of this surface is easily obtained if we assume that the velocity of the water relative to the vanes ought to have a gradually increased value; but a wheel ought not to be made in this way. If the absolute velocity of the water has a continuously diminished velocity, and the particles of the water move in lines curved in only one direction, and then if the velocity relative to the vanes is sometimes increased and sometimes diminished, there is no loss of efficiency, because those velocities are only relative. Such a flow of the water as Fig. 1 represents ought thus to be avoided, and another obtained that gives a better flow. If it is assumed that the water flows as Fig. 1 indicates, it is easy to see that the sheet of water that comes into the wheel at *c*, has a velocity towards the line *gh*, and this velocity di-

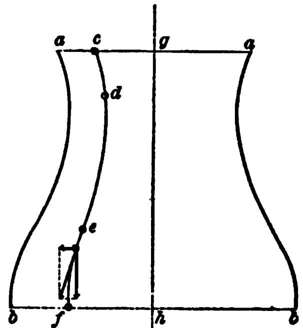


Fig. I

minishes finally to the point *d*, where the water has lost all velocity in this direction. The loss of energy that corresponds to this loss of velocity is to be found as heat in the water. From the point *d* the water again obtains such a velocity; but now in direction from the line *gh*, and it obtains its maximum at the point *e*. The energy that corresponds to this velocity is delivered in its passage from the point *e* to the point *f*, because at this point the water has lost all velocity in this direction, and is converted into heat in the water. Should the water come into this wheel without velocity towards the line *gh*, an impact would arise against the sides of the wheel, because the water cannot instantly change its direction. From this it is easy to understand that those changes of velocities of the water ought to be avoided. In order to make these losses of efficiency as unimportant as possible the water ought to have, as before asserted, a gradually increased velocity from the symmetry plane *gh*, and it obtains its maximum at the outlet of the wheel. This maximum ought to be as little as possible, which takes place if the surface *aabb* in Fig. 1 has such a form as the surface *aaff* in Fig. 5.

If the internal pressure of the water is less than the pressure of the atmosphere, the width at the inlet of the wheel ought to be slightly less than the width at the outlet of the guide case, in order to prevent the air coming into the wheel, so that the water can spread as required.

THEORY FOR RADIAL TURBINE WHEELS.

The notations used in this theory are:

μ = a value that indicates what part of the head of the water is used to give the water the velocity (c_1) between the guides.

c = the velocity that corresponds to the whole head of the water.

c_0 = the velocity with which the water enters the penstock that conveys the water to the wheel.

c_1 = the velocity of the water when it enters the wheel.

c_2 = the velocity of the water in a plane normal to the axis, when it leaves the wheel.

c_3 = the velocity of the water with which it discharges at the lower surface of the water.

U_1 = the relative velocity of the water when it enters the wheel.

U_2 = the relative velocity of the water in a plane normal to the axis when it leaves the wheel.

V_1 = the velocity of the wheel at the inlet.

V_2 = the velocity of the wheel at the outlet.

N_1 = the normal velocity of the water when it discharges from the guide case.

N_2 = the normal velocity of the water when it leaves the wheel.

r_1 = the radius of the wheel at the inlet.

r_2 = the radius of the wheel at the outlet.

$m = \frac{r_2}{r_1}$

B_1 = the width between the sides of the wheel at the inlet.

B_2 = the width between the sides of the wheel at the outlet.

α = the angle between the directions of the velocities c_1 and V_1.

β = the supplement to the angle between the directions of U_1 and V_1.

γ = the supplement to the angle between the directions of U_2 and V_2.

φ = the supplement to the angle between the directions of c_2 and V_2.

θ = the angle (eoe) between the curves of the sides of the wheel and the center line of the cross section of the wheel measured at the outlet of the wheel. See Fig. 4.

H = the effective head of the water.

h_1 = the height between the upper surface of the water and the inlet of the wheel.

h_2 = the vertical distance between the inlet and the outlet of the wheel.

h_3 = the height from the outlet of the wheel to the lower surface of the water.

p_0 = the pressure of the atmosphere per unit of surface.

p_1 = the internal pressure of the water when it enters the wheel.

p_2 = the internal pressure of the water when it leaves the wheel.

δ = the weight of the water per unit of volume.

(1 cubic meter = 1,000 kilograms or 1 cubic foot = 62.4 pounds.

η = the relative efficiency of the wheel.

$L = 1 - \eta$ = the relative loss of efficiency of the wheel.

ξ_1 = a value that indicates what part the openings between the vanes are of the inlet of the wheel, according to the thickness of the vanes.

ξ_2 = a similar value at the outlet of the wheel.

t = the time used for a particle of water to pass through the wheel.

t_x = the time used for a particle of water to pass through the part of the wheel enclosed between the radius r_1 and the arbitrary radius x.

x = an arbitrary radius.

A = the surface enclosed between the sides of the wheel and the distances r_1 and r_2, which surface is obtained if the wheel is supposed to be cut by a plane through the axis of the wheel.

A_x = a similar surface enclosed between the sides of the wheel and the distances r_1 and x.

a = the distance from the center of gravity of the surface A to the center of the wheel.

a_x = the distance from the center of gravity of the surface A_x to the center of the wheel.

ξ_x = the value of ξ that corresponds to the radius x.

ξ = the mean value of ξ for the wheel.

ξ'' = the mean value of ξ for the part of the wheel between the radii r_1 and x.

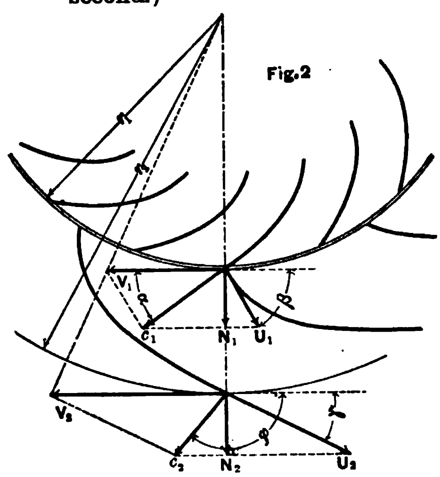
S_x = the removing of the water which takes place at the distance x from the center of the wheel, according to the reaction of the wheel.

Y_x = the distance one point of the wheel at the distance x from the center of the wheel moves during the time t_x.

n = number of revolutions of the wheel per minute.

Q = the volume of water that flows through the wheel per second.

g = the acceleration of gravity (= 9.82 meter per second, or 32.2 feet per second.)



$\sqrt{\mu}\,\sin\alpha$ = a constant that indicates the value of the normal velocity of the water at the inlet of the wheel compared with the velocity that corresponds to the whole head of the water.

The unit of time is one second.

The connection between the values of the angles and the velocities of a wheel are obtained from Fig. 2, according to the laws of the velocities, and are:

$$c_1 = c.\sqrt{\mu} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

$$U_1 = c.\sqrt{\mu}.\sin\alpha\frac{1}{\sin\beta} \quad . \quad . \quad . \quad . \quad . \quad (3).$$

$$V_1 = c.\sqrt{\mu}\sin\alpha(\cot\alpha + \cot\beta) \quad . \quad . \quad . \quad (4).$$

$$N_1 = c.\sqrt{\mu}\sin\alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5).$$

$$c_2 = c.\sqrt{\mu}\sin\alpha.\frac{\cot\alpha + \cot\beta}{\cot\gamma - \cot\varphi}.\frac{r_2}{r_1}.\frac{1}{\sin\varphi} \quad (6).$$

$$U_2 = c.\sqrt{\mu}\sin\alpha\frac{\cot\alpha + \cot\beta}{\cot\gamma - \cot\varphi}.\frac{r_2}{r_1}.\frac{1}{\sin\gamma} \quad . \quad (7).$$

$$V_2 = c.\sqrt{\mu}\sin\alpha(\cot\alpha + \cot\beta).\frac{r_2}{r_1} \quad . \quad . \quad . \quad (8).$$

$$N_2 = c.\sqrt{\mu}\sin\alpha.\frac{\cot\alpha + \cot\beta}{\cot\gamma - \cot\varphi}.\frac{r_2}{r_1} \quad . \quad . \quad . \quad (9).$$

It is to be observed that

$$\sin\alpha = \frac{1}{\sqrt{1+\cot^2\alpha}}$$

when α is an arbitrary angle and thus is obtained:

$$\mu = \mu\sin^2\alpha(1+\cot^2\alpha) \quad . \quad . \quad . \quad . \quad . \quad (10).$$

The value of the loss of efficiency caused by the spread of the water.—In order to find this loss we assume that the water flows through the wheel in such a way as Fig. 5 indicates. The distance one particle of water has to traverse in its passage through the wheel, is the distance $a'e'$, if the point e' is at the distance r_2 from the center of the wheel. The length $a'e' = ae$, see Fig. 3 is approximately

$$a'e' = \pm(r_2 - r_1).\frac{1}{\sin\alpha}$$

which value is always positive. If the curve ae, see Fig. 5, is a parabola, then is

$$\text{tang}\ \theta = \pm\frac{B_2 - B_1}{r_2 - r_1}.\frac{\sin\alpha}{\sin\varphi} \quad . \quad . \quad (11).$$

which value is always positive, and which value is easily found from the figures 3, 4 and 5. Assume that a sheet of water, of the thickness dz, discharges at a distance z from the center line ae, see Fig. 4. Its volume is then:

$$dQ = \frac{dz}{B_2}.Q$$

Its velocity of spread is evidently:

$$N_2\ \text{tang}\ \theta_z$$

The value of tang θ_z is easily found to be:

$$\text{tang}\ \theta_z = \frac{2z}{B_2}.\text{tang}\ \theta$$

and thus is the velocity of spread:

$$N_2.\frac{2z}{B_2}\text{tang}\ \theta$$

From the equations (6) and (9) is obtained:

$$N_2 = c_2 \sin\varphi$$

By use of this value and also of the equation (11) the velocity of spread is found to be:

$$\pm c.\frac{2z}{B_2}.\frac{B_2 - B_1}{r_2 - r_1}.\sin\alpha.$$

The momentum of the water when it discharges from the wheel is a loss of efficiency, and if this loss is expressed in proportion to the natural power, then is the loss by the spread of the water:

$$\frac{1}{Q.\delta.H}\int_{-\frac{B_2}{2}}^{+\frac{B_2}{2}}.\frac{1}{2}.\frac{dz}{B_2}.\frac{Q}{g}.\delta.c_2^2.\left(\frac{2z}{B_2}\right)^2.$$

$$\left(\frac{B_2 - B_1}{r_2 - r_1}\right)^2.\sin^2\alpha \quad . \quad . \quad . \quad (12).$$

because $Q\delta H$ is the natural power of the water. The value of H is, when expressed in c:

$$H = \frac{c^2}{2g} \text{ or } c = \sqrt{2gH} \quad . \quad . \quad . \quad (13).$$

From the equations (12.) and (13.) is obtained after some transformations the loss by the spread to be:

$$\frac{4}{B_2^3}.\left(\frac{B_2 - B_1}{r_2 - r_1}\right)^2.\sin^2\alpha.\left(\frac{c_2}{c}\right)^2\int_{-\frac{B_2}{2}}^{+\frac{B^2}{2}} z^2 dz$$

or after the integration:

$$\tfrac{1}{3}\left(\frac{B_2 - B_1}{r_2 - r_1}\right)^2.\frac{1}{1+\cot^2\alpha}.\left(\frac{c_2}{c}\right)^2$$

The loss of efficiency of a turbine wheel is then:

$$L = \left(\frac{c_2}{c}\right)^2 + \tfrac{1}{3}\left(\frac{B_2 - B_1}{r_2 - r_1}\right)^2.\frac{1}{1+\cot^2\alpha}.\left(\frac{c_2}{c}\right)^2$$

or:

$$L = \left(\frac{c_2}{c}\right)^2\left\{1 + \tfrac{1}{3}\left(\frac{B_2 - B_1}{r_2 - r_1}\right)^2.\frac{1}{1+\cot^2\alpha}\right\}.(14).$$

if it is assumed that the losses of efficiency by the impact of the water against the vanes, the friction between the water and the wheel, and the leak through the space between the guide-case and the wheel are so unimportant that they can be considered of no value. It then remains to find the values of the dimensions of the wheel, that makes equation (14.) of as little value as possible. The value of the loss of efficiency by the spread is very slight and can be neglected in practice, and then:

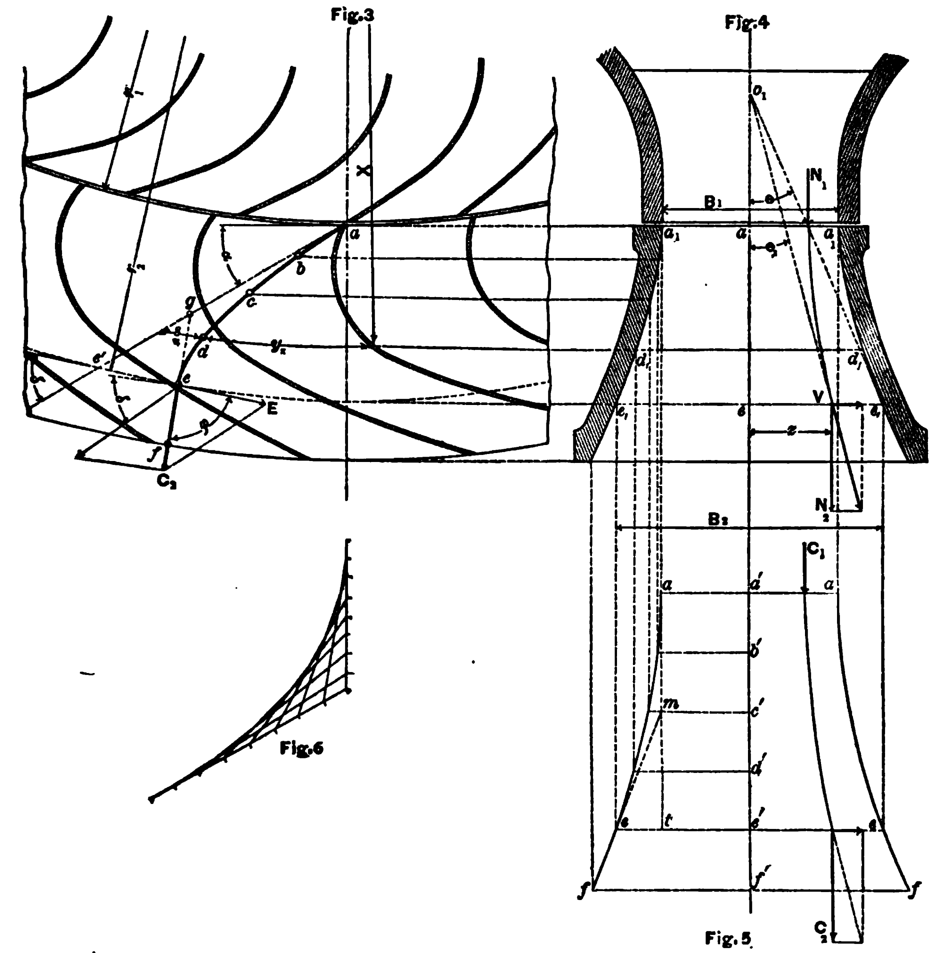


Fig. 3 Fig. 4 Fig. 5 Fig. 6

$$L=\left(\frac{c_2}{c}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (14.)'$$

The derivations of the equations that must be satisfied for all turbines are now to be mentioned:

I. The equation which gives the connection between the dimensions at the inlet and at the outlet of the wheel is obtained, if it is expressed by an equation that the sum of the openings at the inlet of the wheel, multiplied by the normal velocity of the water at the inlet, is equal to the sum of the openings at the outlet of the wheel, multiplied by the normal velocity of the water at the outlet, or

$$Q=2\pi r_1 B_1 \xi_1 N_1 = 2\pi r_2 B_2 \xi_2 N_2$$

By use of the equations (5.) and (9.) is obtained:

$$\frac{c_2}{c}=\frac{\xi_1}{\xi_2}\cdot\frac{B_1}{B_2}\cdot\frac{r_1}{r_2}\cdot\frac{\sqrt{\mu}\sin\alpha}{\sin\varphi} \quad . \quad . \quad . \quad (15).$$

II. The geometrical connection between the angles and the velocities is obtained by use of equation (6.) and is:

$$\frac{c_2}{c}=\sqrt{\mu}\sin\alpha.\frac{r_2}{r_1}\frac{\cot\alpha+\cot\beta}{\cot\gamma-\cot\varphi}\cdot\frac{1}{\sin\varphi}$$

Another not so complicated may be used instead, obtained from equations (6.) and (15.), and is:

$$\cot\alpha+\cot\beta=\frac{1}{m^2}\cdot\frac{\xi_1}{\xi_2}\cdot\frac{B_1}{B_2}(\cot\gamma-\cot\varphi)\quad(16)$$

This equation gives a hitherto unknown relation of great simplicity between the angles and the other dimensions of a wheel.

III. According to the laws for the motion of the water, for the flow of the water from the upper surface of the water to the inlet of the wheel the following equation is obtained:

$$\frac{c_0^2}{2g}+h_1+\frac{p_0}{\delta}-\frac{p_1}{\delta}=\frac{c_1^2}{2g}$$

or:

$$h_1=\frac{c_1^2}{2g}-\frac{c_0^2}{2g}-\frac{p_0}{\delta}+\frac{p_1}{\delta}\quad\ldots\quad(17).$$

The value of $\frac{p_1}{\delta}$ is then:

$$\frac{p_1}{\delta}=h_1+\frac{c_0^2}{\delta}-\frac{c_1^2}{\delta}+\frac{p_0}{\delta}\quad\ldots\quad(18).$$

When the water flows through the wheel then is according to the laws for the discharge of water from vessels that are in motion:

$$\frac{U_2^2}{2g}-\frac{U_1^2}{2g}=\frac{V_2^2}{2g}-\frac{V_1^2}{2g}+h_2+\frac{p_1}{\delta}-\frac{p_2}{\delta}$$

or:

$$h_2=\frac{U_2^2}{2g}-\frac{U_1^2}{2g}-\frac{V_2^2}{2g}+\frac{V_1^2}{2g}-\frac{p_1}{\delta}+\frac{p_2}{\delta}.\quad(19).$$

If the turbine is made in such way that the water discharges into the air when it leaves the wheel, then is $p_2=p_0$. The value of H is then:

$$H=h_1+h_2$$

If the turbine is made in such a way that the water flows from the upper surface of the water to the lower through a penstock, through the wheel, and again through a penstock, and discharges under the lower surface of the water, or the water discharges from the turbine into the tail-race under the lower surface of the water—(see Fig. 7)—then is $H=h_1+h_2+h_3$. The values of h_2 and h_3 can often have negative values (see Fig. 7). Also the value h_1 can be negative;

$H=h_1+h_2+h_3$ then is

$$\frac{c_2^2}{2g}+h_3+\frac{p_2}{\delta}-\frac{p_0}{\delta}=\frac{c_3^2}{2g}$$

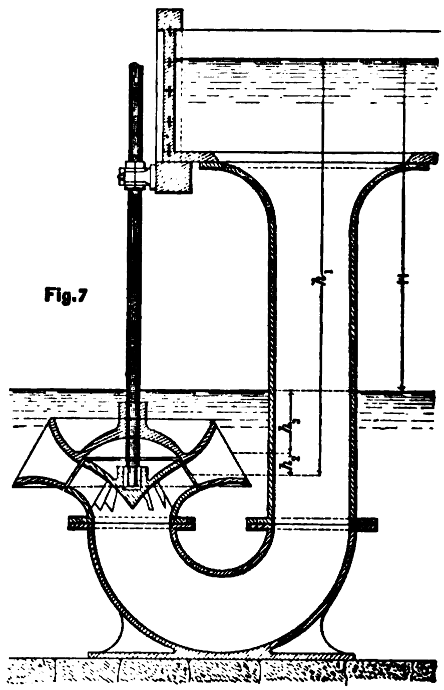
or:

$$h_3=\frac{c_3^2}{2g}-\frac{c_2^2}{2g}-\frac{p_2}{\delta}+\frac{p_0}{\delta}\quad\ldots\quad(20).$$

The value of $\frac{p_2}{\delta}$ is then:

$$\frac{p_2}{\delta}=\frac{c_3^2}{2g}-\frac{c_2^2}{2g}+\frac{p_0}{\delta}-h_3\quad\ldots\quad(21).$$

Fig.7



The values of p_1 and p_2 ought never to be so small as to be nearly equal to zero, and should usually be not less than p_0.

For turbines where the water discharges into the air.—

$$H=h_1+h_2$$

$$H=\frac{c_1^2}{2g}+\frac{U_2^2}{2g}-\frac{U_1^2}{2g}-\frac{V_2^2}{2g}+\frac{V_1^2}{2g}-\frac{c_0^2}{2g}$$

according to the equations (17) and (19). By use of equation (13), and by assuming the value of c_0 as of no value, after some transformations.

$$\left(\frac{U_2}{c}\right)^2=1-\left(\frac{c_1}{c}\right)^2+\left(\frac{U_1}{c}\right)^2+\left(\frac{V_2}{c}\right)^2-\left(\frac{V_1}{c}\right)^2$$

By use of the equations (2), (3), (4) and (8) is obtained:

$$\left(\frac{U_1}{c}\right)^2=\mu\sin^2\alpha\left\{\frac{1}{\mu\sin^2\alpha}+m^2(\cot\alpha+\cot\beta)^2-\right.$$
$$\left.-2\cot\alpha(\cot\alpha+\cot\beta)\right\} \quad . \quad (22).$$

From equations (6), (7) and (15) is obtained:

$$\frac{U_2}{c}=\frac{\sqrt{\mu}\sin\alpha}{\sin\gamma}\cdot\frac{\xi_1}{\xi_2}\cdot\frac{B_1}{B_2}\cdot\frac{1}{m} \quad . \quad . \quad (15').$$

By use of equations (15'), (16) and (22) is obtained:

$$\cot\gamma=\frac{\cot^2\varphi-1+2.\frac{\xi_2}{\xi_1}.\frac{B_2}{B_1}.\cot\alpha.\cot\varphi+\left(\frac{\xi_2}{\xi_1}\right)^2.\left(\frac{B_2}{B_1}\right)^2.\frac{m^2}{\mu\sin^2\alpha}}{2\left(\cot\varphi+\frac{\xi_2}{\xi_1}.\frac{B_2}{B_1}\cot\alpha\right)}$$
$$. \quad . \quad . \quad . \quad (23).$$

The equations that must be satisfied for all turbine wheels of this class are the equations (16) and (23). The relative efficiency of the wheel is by use of equations (14) and (15) obtained to be:

$$\eta=1-\frac{\mu\sin^2\alpha}{m^2}.\left(\frac{\xi_1}{\xi_2}\right)^2.\left(\frac{B_1}{B_2}\right)^2(1+\cot^2\varphi).$$
$$.\left\{1+\tfrac{1}{8}\left(\frac{B_2-B_1}{r_2-r_1}\right)^2.\frac{1}{1+\cot^2\alpha}\right\} \quad . \quad . \quad (24).$$

or approximately:

$$\eta=1-\frac{\mu\sin^2\alpha}{m^2}\left(\frac{\xi_1}{\xi_2}\right)^2.\left(\frac{B_1}{B_2}\right)^2(1+\cot^2\varphi).\,(24').$$

For turbines where the water discharges under the lowest suface of the water:

$$H=h_1+h_2+h_3$$

$$H=\frac{c_1^2}{2g}-\frac{c_2^2}{2g}+\frac{U_2^2}{2g}-\frac{U_1^2}{2g}-\frac{V_2^2}{2g}+\frac{V_1^2}{2g}+$$
$$+\frac{c_3^2}{2g}-\frac{c_0^2}{2g}$$

according to the equations (17), (19) and (20.). By use of equation (13.) and by assuming $c_3=c_0$ is obtained after some transformations:

$$\left(\frac{c_2}{c}\right)^2=\left(\frac{c_1}{c}\right)^2-1+\left(\frac{U_2}{c}\right)^2-\left(\frac{U_1}{c}\right)^2-$$
$$-\left(\frac{V_2}{c}\right)^2+\left(\frac{V_1}{c}\right)^2$$

By use of equations (2.), (3.), (4.), (7.) and (8.) is obtained:

$$\left(\frac{c_2}{c}\right)^2=\mu-1+\mu\sin^2\alpha\left(\frac{\cot\alpha+\cot\beta}{\cot\gamma-\cot\varphi}\right)^2.$$
$$.m^2(1+\cot^2\gamma)-\mu\sin^2\alpha(1+\cot^2\beta)-$$
$$-\mu\sin^2\alpha(\cot\alpha+\cot\beta)^2m^2+$$
$$+\mu\sin^2\alpha(\cot\alpha+\cot\beta)^2$$

From equation (16.):

$$\frac{\cot\alpha+\cot\beta}{\cot\gamma-\cot\varphi}.m=.\frac{1}{m}\quad\frac{\xi_1}{\xi_2}\quad\frac{B_1}{B_2}$$

and then:

$$\left(\frac{c_2}{c}\right)^2=\mu-1+\mu\sin^2\alpha.\frac{1}{m^2}.\left(\frac{\xi_1}{\xi_2}\right)^2.\left(\frac{B_1}{B_2}\right)^2.$$
$$.(1+\cot^2\gamma)-\mu\sin^2\alpha(1+\cot^2\beta)-$$
$$-\mu\sin^2\alpha(\cot\alpha+\cot\beta)^2.m^2+$$
$$+\mu\sin^2\alpha(\cot\alpha+\cot\beta)^2$$

or after some transformations:

$$\left(\frac{c_2}{c}\right)^2=\mu\sin^2\alpha\left\{\left(\frac{\xi_1}{\xi_2}\right)^2.\left(\frac{B_1}{B_2}\right)^2.\frac{1}{m^2}.\right.$$
$$.(1+\cot^2\gamma)-m^2(\cot\alpha+\cot\beta)^2+$$
$$\left.+2\cot\alpha(\cot\alpha+\cot\beta)-\frac{1}{\mu\sin^2\alpha}\right\}. \quad (25.)$$

From this equation by use of equations (15.) and (16.):

$$\cot\gamma=\frac{\cot^2\varphi+\frac{\xi_2}{\xi_1}.\frac{B_2}{B_1}.\cot\alpha.\cot\varphi+\frac{m^2}{2\mu\sin^2\alpha}.\left(\frac{\xi_2}{\xi_1}\right)^2.\left(\frac{B_2}{B_1}\right)^2}{\cot\varphi+\frac{\xi_2}{\xi_1}.\frac{B_2}{B_1}\cot\alpha}$$
$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad (26.)$$

The equations which must be satisfied for all turbine wheels of this class are then: equations (16.) and (26.). The relative efficiency is obtained from equation (24.).

The less the angle α is, the less is the loss of the efficiency caused by the spread of the water; but this loss is very unimportant if the wheel has such a form as Fig. 4 indicates, and the efficiency of the wheels can be assumed to be independent of the value of the angle α, if it is assumed that the value $\sqrt{\mu}\sin\alpha$ is a constant, that indicates the proportion between the velocities N_1 and c. If the normal velocity (N_1) at the inlet of the wheel is assumed to be $\frac{1}{r}$ of the velocity c, then is the value $\sqrt{\mu}\sin\alpha=\frac{1}{r}$

In the theory the value $\sqrt{\mu}.\sin\alpha$ is used even if $\sin\alpha$ is equal to unity, in order to show that it is a constant.

From equation (24.) it is found that the conditions, which must be satisfied in order to obtain good efficiency, are:

The normal velocity of the water when it enters the wheel ought to have but little value—that is to say that the value $\sqrt{\mu}.\sin\alpha$ ought to be slight.

The value m ought to have a great value—that is to say, that outward flow turbines give the best efficiency.

The value of cot φ ought to be as little as possible.

The first two values have the most influence upon the efficiency. The angle φ has not as much, because the value $1+\cot^2\varphi$ is almost constant for small values of $\cot\varphi$.

ON THE SOURCES OF ENERGY IN NATURE AVAILABLE TO MAN FOR THE PRODUCTION OF MECHANICAL EFFECT.

By SIR WILLIAM THOMSON, F.R.S.

From Papers of the British Association.

During the fifty years' life of the British Association, the advancement of Science, for which it has lived and worked so well, has not been more marked in any department than in one which belongs very decidedly to the Mathematical and Physical Section—the science of Energy. The very name energy, though first used in its present sense by Dr. Thomas Young about the beginning of this century, has only come into use practically after the doctrine which defines it had, during the first half of the British Association's life, been raised from a mere formula of mathematical dynamics to the position it now holds—as a principle pervading all nature and guiding the investigator in every field of science.

A little article communicated to the Royal Society of Edinburgh, a short time before the commencement of the epoch of energy, under the title "On the Sources Available to Man for the Production of Mechanical Effect," contained the following:

"Men can obtain mechanical effect for their own purposes by working mechanically themselves, and directing other animals to work for them, or by using natural heat, the gravitation of descending solid masses, the natural motions of water and air, and the heat, or galvanic currents, or other mechanical effects produced by chemical combination, but in no other way at present known. Hence the stores from which mechanical effect may be drawn by man belong to one or other of the following classes:

"I. The food of animals.

"II. Natural heat.

"III. Solid matter found in elevated positions.

"IV. The natural motions of water and air.

"V. Natural combustibles (as wood, coal, coal-gas, oils, marsh-gas, diamond, native sulphur, native metals, meteoric iron).

"VI. Artificial combustibles (as smelted or electrically-deposited metals, hydrogen, phosphorus).

"In the present communication, known facts in natural history and physical science, with reference to the sources from which these stores have derived their mechanical energies, are adduced to establish the following general conclusions:

"1. *Heat radiated from the sun* (sunlight being included in this term) *is the principal source of mechanical effect available to man.* From it is derived the whole mechanical effect obtained by means of animals working, water-wheels worked by rivers, steam-engines, galvanic engines, wind-mills, and the sails of ships.

"2. The motions of the earth, moon, and sun, and their mutual attractions, constitute an important source of available mechanical effect. From them all, but chiefly no doubt from the earth's motion of rotation, is derived the mechanical effect of water-wheels driven by the tides.

"3. The other known sources of mechanical effect available to man are either terrestrial—that is, belonging to the earth, and available without the influence of any external body; or meteoric—that is, belonging to bodies deposited on the earth from external space. The terrestrial sources, including mountain quarries and mines, the heat of hot springs, and the combustion of native sulphur, perhaps also the combustion of inorganic native combustibles, are actually used; but the mechanical effect obtained from them is very inconsiderable, compared with that which is obtained from sources belonging to the two classes mentioned above. Meteoric sources, including only the heat of newly-fallen meteoric bodies, and the combustion of meteoric iron, need not be reckoned among those available to man for practical purposes."

Thus we may summarize the natural sources of energy as Tides, Food, Fuel, Wind and Rain.

Among the practical sources of energy thus exhaustively enumerated, there is only one not derived from sun-heat, that is the tides. Consider it first. I have called it *practical*, because tide mills exist, but the places where they can work usefully are very rare, and the whole amount of work actually done by them is a drop to the ocean of work done by other motors. A tide of two meters' rise and fall—if we imagine it utilized to the utmost by means of ideal water wheels doing, with perfect economy, the whole work of filling and emptying a dock basin in infinitely short times, at the moments of high and low water—would give just one meter-ton per square meter of area. This work done four times in the twenty-four hours, amounts to 1.1620th of the work of a horse power. Parenthetically, in explanation, I may say that the French metrical equivalent (to which in all scientific and practical measurements we are irresistibly drawn, notwithstanding a dense barrier of insular prejudice most detrimental to the islanders),—the French metrical equivalent of James Watt's "horse power" of 550 foot-pounds per second, or 33,000 foot-pounds per minute, or nearly 2,000,000 foot-pounds per hour, is 75 meter-kilogrammes per second, or 4½ meter-tons per minute, or 270 meter-tons per hour. The French ton of 1000 kilos, used in this reckoning, is 0.984 of the British ton.

Returning to the question of utilizing tidal energy, we find a dock area of 162,000 square meters (which is little more than 400 meters square) required for 100 horse-power. This, considering the vast costliness of dock construction, is obviously prohibitory of every scheme for economizing tidal energy by means of artificial dock basins, however near to the ideal perfection might be the realized tide-mill, and however convenient and non-wasteful the accumulator—whether Faure's electric accumulator, or other accumulators of energy hitherto invented, or to be invented,—which might be used to store up the energy yielded by the tide mill during its short harvests about the times of high and low water, and to give it out when wanted at other times of six hours. There may, however, be a dozen places possible in the world where it could be advantageous to build a sea-wall across the mouth of a natural basin or estuary, and to utilize the tidal energy of filling it and emptying it by means of sluices and water.wheels. But if *so* much could be done, it would in many cases take only a little more to keep the water out altogether, and make fertile land of the whole basin. Thus we are led up to the interesting economical question, whether is 40 acres (the British *agricultural* measure for the area of 162,000 square meters) or 100 horse power more valuable? The annual cost of 100 horse power night and day for 365 days of the year, obtained through steam from coals, may be about ten times the rental of forty acres, at £2 or £3 per acre. But the value of land is essentially much more than its rental, and the rental of land is apt to be much more than £2 or £3 per acre in places where 100 horse-power could be taken with advantage from coal through steam. Thus the question remains unsolved, with the possibility that in one place the answer may be *one hundred horse power*, and in another *forty acres*. But, indeed, the question is hardly worth answering, considering the rarity of the cases, if they exist at all, where embankments for the utilization of tidal energy are practicable.

Turning now to sources of energy derived from sun-heat, let us take wind first. When we look at the register of British shipping, and see 40,000 vessels, of which about 10,000 are steamers and 30,000 sailing ships, and when we think how vast an absolute amount of horse power is developed by the engines of those steamers, and how considerable a proportion it forms of the whole horse power taken from coal annually in the whole world at the present time, and when we consider the sailing ships of other nations, which must be reckoned in the account, and throw in the little item of wind-mills, we find that, even in the present days of steam ascendancy old-fashioned wind still supplies a large part of all the energy used by man. But however much we may regret the time when Hood's young lady, visiting the fens of Lincolnshire, at Christmas, and writing to her dearest friend in London (both sixty years old if they are now alive), describes the delight of sitting in a bower and looking over the wintry plain, not desolate, because "wind-mills lend revolving animation to the scene," we cannot shut our eyes to the fact of a lamentable decadence of wind-power. Is this decadence permanent, or may we hope that it is only temporary? The subterranean coal stores of the world are becoming exhausted surely, and not slowly, and the price of coal is upward bound—upward bound on the whole, though no doubt it will have ups and downs in the future as it has had in the past, and as must be the case in respect to every marketable commodity. When the coal is all burned, or long before it is all burned—when there is so little of it left, and the coal mines from which that little is to be excavated are so distant and deep and hot that its price to the consumer is greatly higher than at present, it is most probable that wind-mills or wind-motors in some form, will again be in the ascendant, and that wind will do man's mechanical work on land at least, in proportion comparable to its present doing of work at sea.

Even now, it is not utterly chimerical to think of wind superseding coal in some places for a very important part of its present duty—that of giving light. Indeed, now that we have dynamos and Faure's accumulator, the little want to let the thing be done is cheap wind-mills. A Faure cell containing 20 kilos. of lead and minium charged and employed to excite incandescent vacuum-lamps has a light-giving capacity of 60 candle hours (I have found considerably more in experiments made by myself, but I take sixty as a safe estimate). The charging may be done uninjuriously, and with good dynamical economy in any time from six to twelve hours or more. The drawing off of the charge for use may be done safely, but somewhat wastefully, in two hours, and very economically in any time of from five hours to a week, or more. Calms do not last often longer than three or four days at a time. Suppose, then, that a five-days storage capacity suffices:—(There may be a little steam engine ready to set to work at any time after a four days' calm, or the user of the light may have a few candles or oil lamps in reserve and be satisfied with them when the wind fails for more than five days.) One of the 20-kilo. cells charged when the wind-mill works, for five or six hours at any time and left with its 60 candle-hours' capacity to be used six hours a day for five days, gives a 2-candle light. Thus thirty-two such accumulator cells soused would give as much light as four burners of London 16-candle gas. The probable cost of dynamo and accumulator does not seem fatal to the plan, if the wind mill could be had for something comparable with the prime cost of a steam engine, capable of working at the same horse power as the wind-mill when in good action. But wind-mills as hitherto made are very costly machines; and it does not seem probable that without inventions, not yet made, wind can be economically used to give light in any considerable class of cases, or to put energy into store for other kinds of work.

Consider, lastly, rain power. When it is to be had in places where power is wanted for mills and factories of any kind, water power is thoroughly appreciated. From time immemorial, water-power motors have been made in large variety for utilizing rain power in the various conditions in which it is presented, whether in rapidly-flowing rivers in natural waterfalls, or stored at heights in natural lakes or artificial reservoirs. Improvements and fresh inventions of machines of this class still go on; and some of the finest principles of mathematical hydrodynamics have, in the lifetime of the British Association, and, to a considerable degree with its assistance, been put in requisition for perfecting the theory of hydraulic mechanism and extending its practical applications.

A first question occurs: Are we necessarily limited to such natural sources of water power as are supplied by rain falling on hill country, or may we look to the collection of rain water in tanks, placed artificially at sufficient heights over flat country, to supply motive power economically by driving water wheels? To answer it: Suppose a height of 100 meters, which is very large for any practicable building, or for columns erected to support tanks; and suppose the annual rainfall to be three-quarters of a meter (30 inches). The annual yield of energy would be 75 meter-tons per square meter of the tank. Now one horse-power for 365 times 24 hours is 236,500 foot-tons; and therefore, dividing this by 75, we find 3153 sq. meters as the area of our supposed tank required for a continuous supply of one horse power. The prime cost of any such structure, not to speak of the value of the land which it would cover, is utterly prohibitory of any such plan for utilizing the motive power of rain. We may or may not look forward hopefully to the time when windmills will again "lend revolving animation" to a dull flat country; but we certainly need not be afraid that the scene will be marred by forests of iron columns taking the place of natural trees, and gigantic tanks overshadowing the fields and blackening the horizon.

To use rain power economically on any considerable scale we must look to the natural drainage of hill country, and take the water where we find it, either actually falling or stored up and ready to fall, when a short artificial channel or pipe can be provided for it at moderate cost. The expense of aqueducts, or of underground water pipes, to carry water to any great distance—any distance of more than a few miles or of a few hundred yards—is much too great for economy when the yield to be provided for is *power;* and such works can only be undertaken when the *water itself* is what is wanted. Incidentally, in connection with the water supply of towns, some part of the energy due to the head at which it is supplied may be used for power. There are, however, but few cases (I know of none except Greenock) in which the energy to spare and above that devoted to bringing the water to where it is wanted, and causing it to flow fast enough for convenience at every opened tap in every house or factory, is enough to make it worth while to make arrangements for letting the water power be used without wasting the water substance. The cases in which water power is taken from a town supply are generally very small, such as working the bellows of an organ, or "hair-brushing by machinery," and involve simply throwing away the used water. The cost of energy thus obtained must be something enormous in proportion to the actual quantity of the energy, and it is only the smallness of the quantity that allows the convenience of having it when wanted at any moment to be so dearly bought.

For anything of great work by rain-power, the water-wheels must be in the place where the water supply with natural fall is found. Such places are generally far from great towns; and the time has not yet come when great towns grow by natural selection beside waterfalls for power, as they grow beside navigable rivers, for shipping. Thus hitherto the use of water power has been confined chiefly to isolated factories, which can be conveniently placed and economically worked in the neighborhood of natural waterfalls. But the splendid suggestion made about three years ago by Mr. Siemens, in his presidential address to the institution of Mechanical Engineers, that the power of Niagara might be utilized, by transmitting it electrically to great distances, has given quite a fresh departure for design in respect to economy of rain-power. From the time of Joule's experimental electro-magnetic engines, developing 90 per cent. of the energy of a Voltaic battery in the form of weights raised, and the theory of the electro-magnetic transmission of energy completed thirty years ago on the foundation afforded by the train of experimental and theoretical investigations, by which he established his dynamical equivalent of heat in mechanical, electric, electro-chemical, chemical, electro-magnetic, and thermo-electric phenomena, it had been known that potential energy from any available source can be transmitted electro-magnetically by means of an electric current through a wire, and directed to raise weights at a distance, with ulimitedly perfect economy. The first large-scale practical application of electro-magnetic machines was proposed by Holmes in 1854, to produce the electric light for lighthouses, and persevered in by him till he proved the availability of his machine, to the satisfaction of the Trinity House and the delight of Faraday, in trials at Blackwall in April, 1857, and it was applied to light the South Foreland lighthouse on December 8, 1858. This gave the impulse to invention; by which the electro-magnetic machine has been brought from the physical laboratory into the province of engineering, and has sent back to the realm of pure science a beautiful discovery—that of the fundamental principle of the dynamo, made triply and independently, and as nearly as may be simultaneously, in 1867, by Dr. Werner Siemens, Mr. S. A. Varley, and Sir Charles Wheatstone; a discovery which constitutes an electro-magnetic analogue to the fundamental electrostatic principle of Nicholson's revolving doubler, resuscitated by Mr. C. F. Varley in his instrument "for generating electricity;" patented in 1860; and by Holtz in his celebrated electric machine; and by myself in my "replenisher" for multiplying and maintaining charges in Leyden jars for heterostatic electrometers, and in the electrifier for the siphon of my recorder for submarine cables.

The dynamos of Gramme and Siemens, invented and made in the course of these fourteen years since the discovery of the fundamental principle, give now a ready means of realizing economically on a large scale, for many important practical applications, the old thermo-dynamics of Joule in electro-magnetism; and, what particularly concerns us now in connection with my present subject, they make it possible to transmit electro-magnetically the work of waterfalls through long insulated conducting wires, and use it at distances of fifties or hundreds of miles from the source, with excellent economy—better economy, indeed, in respect to proportion of energy used to energy dissipated than almost anything known in ordinary mechanics and hydraulics for distances of hundreds of yards instead of hundreds of miles.

In answer to questions put to me in May, 1879, by the Parliamentary Committee on Electric Lighting, I gave a formula for calculating the amount of energy transmitted, and the amount dissipated by being converted into heat on the way, through an insulated copper conductor of any length, with any given electro-motive force applied to produce the current. Taking Niagara as example, and with the idea of bringing its energy usefully to Montreal, Boston, New York, and Philadelphia, I calculated the formula for the distance of 300 British statute miles (which is greater than the distance of any of those four cities from Niagara, and is the radius of a circle covering a large and very important part of the United States and British North America), I found almost to my surprise that, even with so great a distance to be provided for, the conditions are thoroughly practicable with good economy, all aspects of the case carefully considered. The formula itself will be the subject of a technical communication to Section A in the course of the meeting on which we are now entering. I therefore at present restrict myself to a slight statement of results.

1. Apply dynamos driven by Niagara to produce a difference of potential of 80,000 volts between a good earth connection and the near end of a solid copper wire of half an inch (1.27 centimeter) diameter, and 300 statute miles (483 kilometers) length.

2. Let resistance by driven dynamos doing work, or by electric lights, or as I can now say, by a Faure battery taking in a charge, be applied to keep the remote end at a potential differing by 64,000 volts from a good earth-plate there.

3. The result will be a current of 240 webers through the wire taking energy from the Niagara end at the rate of 26,250 horse power, losing 5250 (or 20 per cent.) of this by the generation and dissipation of heat through the conductor and 21,000 horse-power (or 80 per cent. of the whole) on the recipients at the far end.

4. The elevation of temperature above the surrounding atmosphere, to allow the heat generated in it to escape by radiation and be carried away by convection is only about 20° Centigrade; the wire being hung freely exposed to air like an ordinary telegraph wire supported on posts.

5. The striking distance between flat metallic surfaces with difference of potentials of 80,000 volts (or 75,000 Daniell's) is (Thompson's "Electrostatics and Magnetism." § 340) only 18 millimeters, and therefore there is no difficulty about the insulation.

6. The cost of the copper wire, reckoned at 8d. per lb., is £37.000, the interest on which at 5 per cent is £1900 a year. If 5250 horse power at the Niagara end costs more than £1900 a year, it would be better economy to put more copper into the conductor; if less, less. I say no more on this point at present, as the economy of copper for electric conduction will be the subject of a special communication to the Section.

I shall only say, in conclusion, that one great difficulty in the way of economizing the electrical transmitting power to great distances, or even to moderate distances of a few kilos., is now over come by Faure's splendid invention. High potential—as Siemens, I believe, first pointed out—is the essential for good dynamical economy in the electric transmission of power. But what are we to do with 80,000 volts when we have them at the civilized end of the wire? Imagine a domestic servant going to dust an electric lamp with 80,000 volts on one of its metals? Nothing above 200 volts ought on any account ever to be admitted into a house or ship or other place where safeguards against accident cannot be made absolutely and forever trustworthy against all possibility of accident. In an electric workshop 80,000 volts is no more dangerous than a circular saw. Till I learned Faure's invention I could but think of step-down dynamos, at a main receiving station to take energy direct from the electric main with its 80,000 volts, and supply it by secondary 200-volt dynamos or 100-volt dynamos, through proper distributing wires, to the houses and factories and shops where it is to be used for electric lighting, and sewing machines, and lathes, and lifts, or whatever other mechanism wants driving power. Now the thing is to be done much more economically, I hope, and certainly with much greater simplicity and regularity, by keeping a Faure battery of 40,000 cells always being charged direct from the electric main, and applying a methodical system of removing sets of 50, and placing them on the town-supply circuits, while other sets of 50 are being regularly introduced into the great battery that is being charged, so as to keep its number always within 50 of the proper number, which would be about 40,000 if the potential at the emitting end of the main is 80,000 volts.

ELECTRIC LIGHTING AT THE PARIS EXHIBITION.

By WILLIAM HENRY PREECE, F.R.S.

From the "Journal of the Society of Arts."

The recent International Exhibition of Electricity in Paris makes an epoch in the history of the practical applications of that science to Arts, Manufactures, and Commerce. I purpose now to refer only to its application to artificial illumination; but there are many other branches fully deserving examination and discussion by this Society. It was, however, as an exhibition of electric lighting that it was principally attractive, and those who saw it for the first time will never forget the vivid impression that the great blaze of splendor produced upon their minds on entering the building. There never can be anything like it again, for as wis dom grows with experience, so no manager of any future Exhibition is likely to repeat that terrific *mélange* of lights that flooded the interior of the Palais de l'Industrie with great brilliancy, but with an impracticable and impossible means of comparing and judging the relative merits of different systems.

For instance, at the forthcoming Exhibition at the Crystal Palace, the building—splendidly adapted for the purpose—will be divided into sections, each section being lit by one, and only one system. But at Paris, Pelion was piled upon Ossa; the British Section, for instance, received rays from at least a dozen different sources. To estimate the value of a Siemens lamp you had to eliminate the disturbing influence of a blazing Crompton; and to admire the star-like Jaspar arc, you had to run the gauntlet of a flock of Swans. The fretful Jamin, or the fitful Jablochkoff, was masked by the steady Gülcher or the brilliant Serrin. In the galleries, however, it was different. Here, different *salles* were illuminated by different systems; a small theatre was lit by the Werderman lamp, and a picture gallery most effectively shown up by the *Lampe Soleil;* a buffet was softly and brightly lit up with the Swan lamp, while Mr. Edison's numerous exhibits, in his own *salons*, were as visible by night as by day, thanks to his own beautiful lamp.

It is not my intention to examine, *seriatim*, the various machines, lamps, and modes of illumination shown. With most of them, you are already familiar. But I purpose to select what appeared to me to be novelties, and what seemed worthy of being brought to your notice, as steps in advance.

On the night of August 29th, there were in operation 277 arc lamps, 116 candles, 44 arc incandescent lamps, 1,500 incandescent lamps, or a total of 1,837 electric lights in all, at the Paris Exhibition. Towards the end of the period during which the show was opened, this number was very largely increased, and I have little doubt that the number reached 2,500 in the beginning of November. Now this army of lamps required power to convert the energy stored up in coal into energy of motion; dynamo-machines to convert the energy of motion into electrical energy; conductors to transport this electric energy to the point to be illuminated; lamps to convert the electric energy into energy of heat, and therefore of light.

The exhibition of engines and machinery was very extensive, although our English manufacturers failed to do what they might have done had they thought as highly of the Exhibition at first as they did afterwards. Many of our manufacturers were conspicuous by their absence. The only extensive display was by Messrs. Robey & Co., of Lincoln, who showed eight of their well-known engines, with a total power of 250 horses, and I have every reason to believe that their success has amply repaid them for their enterprise. Mr. Brotherhood made a small show of his well-known three-cylinder engines and Messrs. Wallis & Stevens, of Basingstoke, sent one of their semi-fixed steam-engines, with their pretty and effective governor for adjusting the speed while in motion—uniformity in speed being an essential criterion of an electric-light engine. The foreigners, for a wonder, far outshone the British in the magnitude of their displays.

One of the most valuable exhibits was made by Messrs. Thomson, Sterne & Co., who showed a new gas engine on a new principle, which attracted a great deal of attention. Gas is destined to play a most important *rôle* in the future of electric lighting. Its function is that of a heat-generator. The energy of the coal exists in gas in a form which can develop more light, when converted into the form of electricity, by the current, than in the form of heat by combustion. Gas engines have a very high theoretical efficiency, and they are free from the dangers of boilers, the neglect of stokers, or the waste of energy in chimneys.

Gas engines on the "Otto" principle, from half horse power to 50 horse power, were very extensively exhibited by France, but the machine of Thomson, Sterne & Co. (Clerk's patent) excelled them all in lightness, compactness, regularity, and safety. One of these engines may now be seen at work at the Smoke Abatement Exhibition at South Kensington, and several have been ordered for private houses. As an adjunct to the gas engine, Mr. Dowson exhibited an interesting and valuable process of making cheap gas for motor purposes. Prof. Ayrton reported that in a series of trials made with a 3½ H. P. (nominal) "Otto" engine, driven by the Dowson gas, one H. P. (indicated) was obtained per hour by the consumption of gas derived from 1.46 lbs. of coal. For larger engines he anticipated a consumption of only 1.2 lbs. per indicated horse power per hour. You will have a paper during the Session by Mr. Dowson himself, describing his mode of manufacture. When perhaps 6 lbs. of coal per horse power per hour are consumed in the present electric-light steam-engines, you can form some idea of the economy to be effected by cheap gas.

Dynamo-machines — machines which convert the energy of motion into electrical energy, through the medium of magnetism—were exhibited in abundance, of all kinds and forms, from the original apparatus of Faraday, made with his own hands, to Mr. Edison's latest development of this wonderful source of electric currents. There are two kinds of machines—the one producing currents from fixed and permanent steel magnets, the other from electro-magnets, excited by the currents which they themselves generate. Each kind is also sub-divided into two others, in one of which continuous currents are produced, flowing in one direction, called the *continuous current machine;* and in the other alternate currents, called the *alternate current machine*, where the current rapidly reverses and changes its direction. The production of currents by these machines is due to the simple fact discovered by Faraday, that if a conductor, such as a copper wire, be moved rapidly through a magnetized space, or a magnetic field, as it is called, this conductor is electrified so that, if its two ends be connected, a current flows. The intensity of this current depends, first, on the intensity of the magnetism present, on the velocity with which the conductor moves through the field, and on the direction with which it cuts the lines of magnetic force which permeate the magnetic field. The magneto-electric kind—the manufacture and invention of M. de Meritens—are very much approved of by our Trinity House for lighthouse purposes, and a very fine display of them was made by M. de Meritens, who seemed to live in the Exhibition, for he was always there, and who never seemed to tire of giving his clear and able descriptions. He exhibited alternate and continuous current machines, and he richly deserved the gold medal that was accorded to him. The exhibition of dynamo-machines was rendered very interesting by the exhibition of an early machine of Elias, of Haarlem, of 1842, and of Pacinotti's machines of 1861. The former was shown in the Dutch Section, and the latter in the Italian. Here we have the germs of all the present machines, and by whatever name a machine may be known, it can be traced back to these original types. The Pacinotti apparatus has been very greatly improved by Gramme, and by Siemens—forms well known to every one—but it has received its greatest development in the Edison machine, which was one of the wonders of the Exhibition. As this was one of the greatest novelties, I must briefly describe it. In the first place, I must point out that the machine is larger than any one that has ever been made before. It weighs, with engine and bed plates, 20 tons, and it can produce a current of electricity of nearly 900 amperes.* As the largest machine of the Gramme type weighs scarcely one ton, and produces a current of but 93 amperes, the difference becomes striking. Now, Mr. Edison has struck out three new paths, first—in the bulk and form of his electro-magnets, second—in the size and construction of his armature, and third—in the low resistance of his revolving coil. By the first, he secures an intense and concentrated magnetic field, by the second he secures a high cutting velocity for the moving conductor through this field, and by the third, he secures a very powerful current to be distributed among a great number of lamps with the least possible waste of energy. The long and bulky coils, 8 feet long, which constitute his electro-magnet, have excited the surprise of many electricians, but there is no doubt that he has arrived at this form after many careful practical experiments, supported by the mathematical investigations of Professor Rowland—a very high authority—and that the result is to obtain an intense field in a large space, with the least absorption of electrical energy in the coils. With 350 revolutions per minute he is able to produce an electro-motive force of 110 volts, which an ordinary Gramme machine can only attain with over 1,000 revolutions per minute. His field-magnets are wound with copper wire, which have a resistance of 30 ohms, and which are connected as a shunt to the main circuit, as was originally done by Wheatstone, and is now followed by Dr. Siemens and Sir William Thomson. The armature is not wound with wire, but is constructed with solid bars of copper $\frac{7}{8}$ in. by $\frac{1}{2}$ in. section, and

*The largest Brush machine weighs two tons, and absorbs 40-horse power.

3¼ feet long, which are well insulated from each other, and are most ingeniously connected at their ends by copper discs, so that all the bars, of which there are 138, form one continuous circuit, whose total resistance is only 0.008 of an ohm. The diameter of the armature is 28 inches. The core of the armature is made up of 1,700 thin iron discs insulated from each other by paper, and well clamped into a solid mass by bolts. This is done to avoid the heating effects due to so-called Foucault currents induced in the metal and absorbing or wasting energy. The iron core of the armature becomes thus magnetized, and it concentrates the field to the space through which the conductor moves, as is done in Siemens' and other machines.

There are two great troubles in existing machines, want of uniformity in their motion and the slipping of belts. The former is met by governors, and the latter by direct gearing. Steadiness of motion is most essential, otherwise we have that painful throbbing of the light that is so irritating to the eyes. Mr. Edison connects his armature direct to his steam motor, which is a high-pressure engine of the Allen-Porter type, governed by an ingenious centrifugal regulator, and rotating very uniformly at 350 revolutions per minute, without any multiplying gear whatever. When the machine is giving out its maximum commercial effect it absorbes 125-horse power, the external resistance should be 16 times that of the armature, the electro-motive force 110 volts, and the current consequently 860 amperes. It is not safe to exceed this limit, for the armature then becomes unduly heated. A special blower is added to direct cold air on the armature to keep down the heat, when the work of the machine approaches its limit. The brush is a special feature of the machine. The absence of sparking was very striking. Mr. Edison coats his brush and commutator with an amalgam of copper, which diminishes the electrical resistance of contact, reduces the heat, and prevents sparking.

Those who are interested in this machine—and every one should be, for it is a decided step in advance—will soon have an opportunity of seeing it at work at 57, High Holborn.

There was a very interesting form of Gramme machine shown, which was maintained at a velocity of 2,400 revolutions per minute, and was said to generate an electromotive force of 2,000 volts. It maintained 60 Jamin candles alight. But one of the best and most compact forms of Gramme was that shown by the British Electric Light Company, designed by their engineer, and made for them by Messrs. Emerson, in Stockport.

The display of lamps was the display of the building. There were very few novelties among arc lamps. An arc lamp consists of two sticks or rods of carbon, which are kept apart a small fraction of an inch while the current flows through them, but which comes together when the current ceases. Across the interval separating them there is a steady flow of electricity, accompanied by a slow consumption of the carbon of each rod. This flow of electricity produces high temperature, and intense incandescence and combustion of the carbon particles. This is the arc. One lamp differs from another only in the way in which the carbons are moved forward as they consume, so as to maintain the resistance equal and the light steady. Among arc lamps, that which signaled itself out among all its compeers, for steadiness and brilliancy, was the Jaspar lamp, exhibited in the Belgian Section; but it had the disadvantage of absorbing all the energy of one machine. Among those that admitted of having a number on one section, perhaps the simplest in its construction was the Gülcher, exhibited in the Austrian Section; but the most effective and original was the "Pilsen" lamp, the invention of Messrs. Piette & Krisik. It is called the "Pilsen" lamp, from the place of its birth, and from the want of euphoniousness in the names of its inventors. It was exhibited in the Austrian Section, and also in the British Section, by Mr. Fyfe. The carbons are kept apart by a sucking coil when the current flows; they are regulated by a second sucking coil worked on a shunt. The peculiarity of the lamp consists principally in the shape of the core that controls the carbon—it is wedge-shaped at each end; in action is wonderfully regular, and almost perfect. Six lamps were worked in one circuit by a Schuckert machine.

The *Lampe Soleil*, which holds an intermediate position between arc and incandescent lamps, made a very effective display in the picture gallery, where there were 20 lamps in 10 lanterns. It is to be seen in London lighting up the Panorama in Westminster. It is a fixed, steady, durable lamp, giving a soft yellowish light, which is due to the fact that the arc maintains in incandescence a highly refractory substance like marble, between the two ends at the carbon. It is a very simple lamp, for it involves no mechanism whatever; but it is said to absorb a great deal of power, though I have seen no reliable figures of its performance. Its consumption of carbon is remarkably small. It is worked by an alternate current machine, which, like most of these machines, made a most unpleasant hum.

Carrè made a very fine display of carbons for arc lights, for the manufacture of which he is so famous, in which the regularity of form, of structure, and of composition, is said to be absolute; but it is very questionable whether this is really the case in practice, for the irregularity of the arc lights is chiefly due to impurities and irregularities in the carbon. Moreover, the very vast discrepancies that are found in the photometric measurements of the same lamp at different times, or by different persons, may be due to the irregularities in the structure of the artificial carbon rods.

No one can deny that the Jablockhoff candle has done good service in the cause of electric lighting; but I am afraid that the Exhibition in Paris has sounded the knell of all forms of candle, as well as those of the Werderman type. The rising favorite is the incandescent lamp, pure and simple. The display made by Mr. Swan in the buffet, in the Congress Hall, and in the Pavilion at the Post-office, was brillant and effective. The light was soft, uniform, and yellow. The incandescent light is totally free from those bright rays that are so injurious to the eyes, so uncomplimentary to the complexion, and so irritating to the worker, if they are accompanied with the least unsteadiness. It is so readily under control; it requires no skilled labor to replace it or attend to it; it can be fixed anywhere; it can be worked into the fixtures and decorations of a room, and it does not damage them, as gas and oil do. Incandescent lamps can be worked by either continuous or alternate current machines. In fact, the chief lesson of the Paris Exhibition is this, that the arc light is specially suited for external illumination, and that incandescent lamps are eminently adapted for internal and for domestic illumination. This lesson has been carried into practice at the Savoy Theatre, where nothing can be more effective or more efficient than the illumination of the auditorium. One can breathe pure air, feel cool, and can sit out a play without incurring a headache. There were several incandescent lamps shown at Paris besides those of Mr. Swan, notably those of Maxim and Lane-Fox; but that which possessed the greatest novelty, and was decidedly the most efficient, was that of Mr. Edison. The distinctive character of the Edison lamp is the remarkable uniformity of its texture and light-giving power. The lamp consists of a fine filament of carbon inserted as a part of the electric circuit in a glass globe, which has been exhausted of air to the utmost limit of workshop skill. A fine, uniform quality of Japanese bamboo has been selected as that which gives the finest filament for carbonizing. The bamboo is cut by special machinery into the required dimensions, and inserted in a mould, which is placed in a furnace, and raised to a very high temperature, and from which the filament comes out shaped and carbonized. Naturally grown vegetable fiber has been found to give a more uniform texture than any artificially-formed carbon. The ends are cut flat, and squeezed inside copper clamps, which are then welded together by electro-plating. The copper clamps being soldered to platinum loads that are sealed through the glass, and are connected to the conductors. Perfect sealing is obtained by flattening the mass of the tube, through which the fine platinum wires pass into a solid bar, so as to well fuse the wires and glass together. It is a fortunate thing for the permanence of the incandescent lamp that the co-efficient of expansion, due to heat, of glass and platinum is practically the same.

The normal lamp consists of a filament 6 inches long, which gives a resistance of 240 ohms when cold, and, when permeated by a current of 0.8 ampere, gives a light equivalent to 16 sperm candles.

The half lamp is constructed with a carbon filament of just half the length and half the resistance, and gives eight candles. Other lamps are made with two and four horse-shoe filaments, so as to increase the light-giving power. The features of carbon, which render it so highly adapted for incandescence, are its electrical resistance, its high refractory character, and its stability. The illumination of a filament and its durability are functions of the current that passes; the more intense the current the higher the temperature, and therefore the brighter the light and the shorter its life. At a temperature of about 1,000° carbon becomes red, at 2,000° it is white, and the higher the temperature the whiter it gets, until it fuses. A current of 0.8 of an ampere maintains an Edison filament at about 2,000°, when it gives a light of 16 candles, and it lasts on an average 1,000 hours. A stronger current will give a much better light, but the carbon will not last so long. If it were possible to find a form of carbon, or any other material, which would be so refractory that we could transmit through it much stronger currents, the incandescent lamp would rival the arc lamp in brilliancy and power.

The destruction of the carbon filament in incandescent lamps is due to what is called the Crookes' effect, a very slow transference of carbon, in a molecular shower, from the one heel to the other heel of the horseshoe, until a breakdown takes place at the former point. The better the vacuum the slower this effect. Alternate current machines are said to lengthen the life of the carbons, by equalizing the distribution of molecules on each heel, but they do so at the expense of efficiency.

Many devices were shown for measuring the quantity of electricity consumed in any place by electric lamps; but that adopted by Mr. Edison is sufficiently simple and accurate for all practical purposes. A glass cell contains two copper plates immersed in a solution of sulphate of copper. A definite proportion (0.001) of the current that passes through the house passes also through this cell, and removes copper from one plate and deposits copper on one plate. The weight of copper deposited is an exact measure of the current used. There are two such cells—the one in charge of the consumer and the other of the supplier. They thus check each other.

Various plans were shown in different parts of the Exhibition to diffuse the light, but the most effective was that in *Salle* 15, where a Jaspar lamp filled the room with a shadowless light, by throwing a light on to a white screen above the lamp, whence it was scattered. The lamp itself was invisible. This plan is not novel. It was suggested by the Duke of Sutherland, and has been adopted by Mr. Schwendler in India.

The proper distribution of light is a problem that remains to be solved. It is argued that an arc is so much superior to an incandescent light, that one-horse power in the former gives you ten times more light than in the latter. This is true; but, on the other hand, to obtain a subdued light sufficient for your purpose, you must either put the arc lamp far away or tone it down by shades, and therefore waste it; whereas an incandescent lamp can be toned down, by regulating the current, to any color you like, and it can be fixed just where it is wanted. One-horse power will give you 1,500 candles in an arc, and only 160 candles in 10 incandescent lamps; but these 10 lamps can be so distributed about your space to be lit, as to illuminate your surface or objects with a better light than the arc.

Curiously enough nothing whatever was done in Paris to improve the illumination of streets. The Avenue de l'Opera, the first street practically lighted by electricity, still remains as it was in 1878; but prior to the opening of the Exhibition, a portion of the Boulevard des Italiens was lit up by four De Mersanne lamps, suspended high up, at wide intervals, over the center of the road. The effect was very fine, but the lamps were very bad. This is the true way of illuminating streets, and it is to be regretted that such an experiment is not tried in London. Street illumination in England by electricity up to the present time is, as a rule, a questionable success.

The question remains for discussion: Has the electric light been brought within the region of practical domestics? I have no hesitation in saying that it has; but whether it can be brought into economical contrast with gas, experience alone will show. Several houses are already illuminated by its agency; others are in hand, my own amongst the number; and when we next meet to consider this subject, I may be able to answer the question with actual facts.

One word as regards the danger of electric lighting. There is no use blinking our eyes to the fact that electricity can be a dangerous servant in the hands of the careless and ignorant; in the hands of the skilled it has less danger than gas, or even oil. The installation of the wires must be controlled by experience and knowledge. I have more than once called attention to this fact, and my warnings have been received with abuse; but in Paris there were no less than five incipient fires, from the wires coming in contact with each other, in the Exhibition building. The *Times* correspondent in Vienna implies that the frightful disaster to the Ring Theatre was due to this cause. The instances in New York are so numerous that the Board of Fire underwriters have issued the following rules:—

"1. Wires to have 50 per cent. excess of conductivity above the amount calculated as necessary for the number of lights to be supplied by the wire.

"2. Wires to be thoroughly insulated and doubly coated with some approved material.

"3. All wires to be securely fastened by some approved non-conducting fastening, and to be placed at least 2½ inches for incandescent light, and 8 inches for arc lights, from each other, and 8 inches from all other wires and from all metal or other conducting substance, and to be placed in a manner to be thoroughly and easily inspected by surveyors. When it becomes necessary to carry wires through partitions and floors, they must be secured against contact with metal or other conducting substance in a manner approved by the inspector of the Board.

"4. All arc lights must be protected by glass globes enclosed at the bottom, to effectually prevent sparks or particles of the carbons from falling from the lamps; and in show windows, mills, and other places where there are materials of an inflammable nature, chimneys with spark arresters shall be placed at the top of the globe. Open lights positively prohibited. The conducting framework of chandeliers must be insulated and covered the same as wires.

"5. Where electricity is conducted into a building (from sources other than the building in which it is used) a shut-off must be placed at the point of entrance to each building, and the supply turned off when the lights are not in use. Applications for permission to use electric lights must be accompanied with a statement of the number and kind of lamps to be used, the estimate of some known electrician of the quantity of electricity required, and a sample of the wire (at least three feet in length) to be used, with a certificate of said electrician of the carrying capacity of said wire. The applications should also state where the electricity is to be generated, whether the connection will have metallic or ground circuit, and, as far as possible, give full details of the manner in which it is proposed to equip the building."

These rules are very simple, and are necessarily carried out by every qualified electrician, but an additional security is obtained by Mr. Edison, by inserting in every branch wire a "safety catch," which is a short piece of lead wire that instantly melts if the strength of the current exceeds a certain value, and thus ruptures the circuit, stopping the flow of electricity, and producing safety.

The completeness of Mr. Edison's exhibit was certainly the most noteworthy object in the exhibition. Nothing seems to have been forgotten, no detail missed. There we saw not only the boilers, engine, and dynamo machine, but the pipes to contain the conductors; the conductors themselves, heavy and massive, for Mr. Edison recognizes the waste of energy that must occur in small conductors, the insulation, the fixtures, the brackets, the safety catches, the lamps, devices to avoid the effects of expansion and contraction through changes of temperature, meters to measure the current used, regulators to control the consumption of fuel. In a properly regulated system there ought to be no waste of fuel. The engine driver has an indicator which shows him exactly what current is going out, and he has simply to regulate his firing by this indicator. Moreover, by the use of a rheostat, he is also able to regulate the outgoing current so that he is able to maintain a perfect ratio between the fuel consumed and the light evolved.

The question that determines the size and insulation of conductors is a commercial one, and is regulated by the relative economy of waste of energy or interest on capital expended. If an expenditure of £100 per mile saves you £10 a year in fuel, it is clearly better to expend £100 on your conductor. If, on the other hand, it would save you only £2 a year, it is better to utilize your capital elsewhere. Every inch of conductor means waste of energy; the shorter and heavier it is the less the waste; but as some waste is imperative, it is simply a matter of calculation to determine which shall be wasted least, capital or fuel.

The system is self-regulating, if the electromotive force is kept constant, and the resistance of the lamps be uniform. We have the dynamo machine at one end of the circuit, and a lamp at the other. The circuit is complete; a small current flows, which is determined by the resistance of the lamp alone, if the main conductors are made sufficiently large to neglect their resistance. Additions and subtractions of lamps only vary the resistance, and, therefore, the current. Turning off one lamp does not interfere with the rest. The limit of the number of lamps inserted is determined by their resistance and by the heating of the armature; hence the value of high resistance in the lamps, and low resistance in the armature of the dynamo machine. Every lamp induces, as it were, its own current. We have not a store of electricity which has to be subdivided, but we generate our energy as we want it. This is the promising feature of the system. It is a principle of multiplication, rather than of sub-division, and leads one to anticipate economy in its working. Mr. Edison's system has been worked out in detail, with a thoroughness and a mastery of the subject that can extract nothing but eulogy from his bitterest opponents. Many unkind things have been said of Mr. Edison and his promises; perhaps no one has been severer in this direction than myself. It is some gratification for me to be able to announce my belief that he has at last solved the problem that he set himself to solve, and to be able to describe to the Society the way in which he has solved it.

It may be taken as a rule, that any system dependent on the exercise of abnormal energy is certain sooner or later to break down; we all of us hate personal supervision, and personal supervision at home is a species of abnormal energy. This is the great secret of the success of gas. It is the cause of the slow progress of the arc light; but it is because the incandescent light promises to rival gas in this respect, that such a future is open to it.

The awards at the Paris Exhibition were liberally bestowed by the jury, perhaps too much so; but matters were hurried up towards the end, owing to political difficulties, and the conclusions were necessarily hasty. No proper measurements or tests were made by any jury, but a committee, presided over by M. Tresca, has since been formed to continue the work, and there is no doubt that most valuable results will be obtained, for the desire of the jury to procure reliable measurements has been very generally met by the exhibitors. I had great hopes of being able to give you the results to-night, but the reports are not yet complete.

We shall all, very soon, have a repetition on a different scale, and in a different way, at the Crystal Palace, and I have little doubt that, in its way, the Crystal Palace Exhibition will be as fine and as interesting as that of Paris.

DISCUSSION.

The Chairman said he could not open the discussion better than by calling on Mr. Johnson, the representative of Mr. Edison.

Mr. Johnson said he did not know that he could supplement what had been so well said by Mr. Preece, so as to add to the interest of the subject, but he should be ready to explain anything which had been left unexplained, and he would also illustrate, further, the use of some of the apparatus. He wished, however, to say that Mr. Edison's system was not merely a system of electric lighting; but the novelty of his system lay in this, that he contemplated the manufacture of electricity on a large scale at a central station, and its universal distribution throughout the entire area of the city where it was established, to be used by uneducated or unscientific people, without the supervision of trained experts in the employment of the company. They proposed to put the electric light into houses in such a simplified form, and with such provisions, as to render supervision entirely unnecessary; to bring the lamps within the care of ordinary house servants, no matter how ignorant they might be; and in such a way that no damage or waste was possible. The electricity thus converted into light might also be converted into power, by means of an electro motor; and it might be utilized in a variety of ways, such as for ringing bells, &c. The annoyance of maintaining a battery, as well as its expense, had hitherto proved a bar to its general use, but when electricity could be supplied and paid for only as used, to be shown by a meter, an immense deal of work, such as driving sewing machines, &c., would be done by it. There had been a good deal of talk about a regulator, and Mr. Preece had shown that one might be made to maintain an even pressure throughout an entire district lighted from one station, no matter how many lamps were lighted by it. They preferred to have such a regulator with personal supervision, just as gas companies regulated the pressure on their mains as required, rather than employing any automatic device, which was liable to get out of order. [Mr. Johnson here showed how the amount of current could be increased or diminished at will, so that when fewer lights were in use, the quantity would be diminished accordingly.] The man in charge of the central station would regulate the current by a sample lamp kept alight there. He had been asked whether the replacement of the lamps, when used up, was expensive or difficult. In answer to that, he might say that in New York, where they were making arrangements to light up a central district of a mile square, they proposed to supply every consumer with all the lamps he might use, free from cost, simply charging the cost of the lamp in the current supplied and paid for on his meter. The first cost of the lamps was very small to them, and they therefore preferred supplying them to subjecting the consumer to the annoyance of having to purchase them. [Mr. Johnson here unscrewed a lamp, and attached another, to show the readiness with which a change could be effected.] A question had also been asked him, whether a single light could be raised or lowered; and there was a lamp made in which this was provided for, but it was more expensive and complicated, and was not recommended. There were very few cases where such would be required, because you need not leave a light on as in the case of gas, in order to light up when required, as you only had to turn it on, and it lit itself.

Sir Henry Tyler, K.C.B., moved a vote of thanks to Mr. Preece, but remarked that the paper hardly answered to the title, inasmuch as it was mainly devoted to an explanation of Mr. Edison's lamps, and he thought there might have been a little more time bestowed upon other lamps. He was far from wishing to disparage the Edison lamp, and no one had more sympathy than he had with American inventors; but he would suggest that the title of the paper should be altered when printed.

Mr. E. Crompton said he had been much interested in the paper, but he must concur to some extent in Sir H. Tyler's remarks. Many, if not all, of the merits of the Edison lamp were common to other incandescent lamps. He, therefore, thought Mr. Swan and Mr. Lane-Fox ought not to be passed over in silence, or Mr. Maxim, the other great American inventor. Mr. Preece had been rather hard on the arc systems, which he said had made comparatively little progress; but in reply to that, he would ask the meeting to look at the length and breadth of England, where, since that time last year, there had been from 900 to 1,000 installations of the electric light, which, with the exception of 30 or 40, were all on the arc system, and, with very few exceptions, they were all working most successfully. The incandescent systems were working equally successfully, but the whole system was an infant compared to the arc, and had not yet been worked on a sufficiently large scale to judge of its merits. It had hitherto been placed in circumstances not best suited for it. The lighting of the Savoy Theater was a great success, in his opinion, but no one could say that that vast open space could not be lit more satisfactorily with arc lights, if good ones, and properly managed. The arc light hitherto had had to struggle with the great difficulty of getting homogeneous carbons; but new manufacturers were setting to work, and he believed the trade of making these carbons would soon become one of the great industries of the country. It required nothing but the enormous demand, now springing up, to produce splendid carbons, which would give a perfectly satisfactory light.

Mr. J. N. SHOOLBRED said he had nothing to add to Mr. Preece's descript on of the Paris Exhibition, but he thought his remarks as to the future sphere of the arc light and the incandescent light respectively should be somewhat modified. He did not think the arc light need be confined merely to large open spaces. It was a question of the enormous difference of mechanical energy; and a case which recently came under his notice would illustrate this. It was the interior of a building considerably larger than that hall, which it was found would require about 6-horse power to light it by the arc system, whilst on the incandescent system it would have taken nearly 40-horse power, and from 170 to 200 lights. With regard to the experiments shown that evening, he must fully concur in what had been said as to the beautifully steady character of the lights, but at the same time it was only fair that due credit should be given to other inventors.

Mr. HUGH CLEMENTS remarked that Mr. Edison had evidently gone beyond any one else, up to the present time, in the manufacture of his 20-ton machine at any rate. Mr. Preece, of course, could not enter fully into the details of all the lights; but he understood him now to withdraw a statement he had made on a former occasion, that it was impossible for private houses to be lit up by electricity from a central station. There was evident proof that this was being done in New York, and he hoped the time would soon come when they would see the same thing in London.

Captain VERNEY, R.N., said it might be interesting to the meeting to hear the opinion of one of the general public, entirely unconnected with any electrical interest. He had visited the Paris Exhibition twenty or thirty times, and had been many times in both the Edison and Swan rooms. He must say that he came away with the impression that on the whole the Lane-Fox was the most satisfactory exhibit. He was also much impressed with the beauty of the *Lampe Soleil*, which Mr. Preece had alluded to, but not described very minutely. One of its great beauties was, that you could introduce other substances as a bridge between the carbons, and thus vary the color and quality of the light. The light was exceedingly soft and agreeable, being generally overhead, and it seemed to him an enormous advantage to be able to introduce marble, magnesium, or some other substance, and so tone the light as to be suitable to the place to be illuminated. He hoped those who had the management of the Exhibition at Crystal Palace, would enable the general public to gather from it more information than was available at Paris. There they were furnished with an incomprehensible catalogue, referring to numbers which did not exist, and to rooms which could not be found. It was a most perplexing thing for any one with the average amount of intelligence and energy, to learn anything from the Paris Exhibition.

Mr. LASCELLES SCOTT did not propose to launch upon the vexed question with which the discussion opened, further than to suggest that, as Mr. Preece had on former occasions spoken rather adversely to Mr. Edison, he felt constrained now, with more information, to do him full justice. He thought the time was hardly arrived to pronounce definitely that the arc light was only suitable for large open areas, and that the incandescent system was best for internal use, or *vice versa*, because in all probability, in a few years, such an opinion would be very much modified. Judging from his own small experience, he desired to place on record his opinion that probably the domestic lamp of the future would be one in which the prominent features of both systems were combined, which would illuminate a room alternately, or almost at the same time, by either a small arc or an incandescent lamp. There was already a system which professed to do something of the kind.

The CHAIRMAN said he thought that the last speaker had really given the answer to the objection raised by Sir H.

Tyler, by referring to Mr. Preece's desire to restore the equilibrium of the balance, which, on a former occasion, had been unduly depressed on one side. Passing from this matter and going to the real subject of the paper, they had before them a remarkable example of the incandescent light, and he thought they must all agree that if this light could be introduced into houses, in the same way as gas, and at no greater, or a very little greater, expense, it would be forthwith adopted. A lamp which did not vitiate the atmosphere in the least, which gave off but a small amount of heat, which was capable of being absolutely extinguished, and then renewed again in a moment, was one which all would willingly take instead of a gas lamp, which certainly did pollute the air, heated it inconveniently, and if there were too much pressure, or the burner were out of order, smoked and spoiled the furniture and pictures. Under these circumstances he thought it could not be doubted that if they could all, by a mere word, change their gas fittings and lights to such as they saw there, that word would be uttered; but then came the question, how near were they to that being practically and commercially possible? He believed they were very near to it. It had been said, and truly, of the electric light, as one of Dickens' characters said of the steam engine, that it was yet in its infancy. Sometimes infants grew up well, and became a pleasure to their parents; sometimes they grew up ill; but he believed this infant would turn out a credit to its parents, and that they would soon have the electric light laid on in the manner which had been stated. The difficulties at present attendant on applying it to individual houses, were those connected with the motive power, a large question which he could not then fully go into; but there was a system, somewhat inaccurately called "storage of electricity," by which there might be brought into any house a number of boxes, not storing electricity, but each containing an apparatus which had, by the agency of electricity, been put into a condition competent to develop electricity in an absolutely regular manner, a most needful quality for the satisfactory production of the incandescent light, although he must say no want of steadiness was observable from the working of the engine that evening. You could, therefore, by the aid of these boxes, practically have electricity brought into your house, as you had gazogenes, ready charged, or as he remembered many years ago, portable gas was carted to houses in this city. Unless there were some such system as that, persons who wanted to use the electric light had to resort to a motor of some kind, and there was the choice between steam engines and gas engines. A large steam engine at present was more economical than a gas engine, but on the other hand, it required a more skilled attendant. To work a gas engine, you had to do little more than turn a tap, and to oil occasionally; the stoker and engine driver were really at the gas works. The manager there supplied a regular flow and pressure of gas, and in that way the labor of attendance to each engine was reduced to a minimum. In the case of small engines, this non-necessity for skilled attendance reduced the cost practically far below that of a steam engine. For that reason, he believed, that the individual lighting of houses would be done by gas engines, and that if you took the gas with which your house was lighted, and applied it to work an engine, you would obtain a greater amount of light from incandescent lamps than by burning the gas direct. The calculation had been gone into very carefully, and were it not for the cost of replacing the lamps, it was quite clear that even now economy was considerably on the side of electricity. He was glad to hear from Mr. Johnson that in America the company preferred to include the replacement of the lamps in the fixed charge for the electricity; but that could hardly be done where each man had to produce his own electric current. A thousand hours was stated to be the average life of these lamps, some being much above and others much below the average. The other day a committee, of which he was a member, did not feel it safe to calculate the average at more than 500 hours, and then putting the cost of renewal at 5s., it turned out that that, added to the fuel, made the electric lighting rather dearer than gas, and they had deferred the consideration of the matter for a few weeks to obtain further information. But if electricity could be laid on to houses, no doubt the problem would be, to a large extent, solved. One of the great difficulties was in the meter, but they had had one of a very ingenious and apparently efficient character exhibited that evening, and that might render practicable the establishment of a company for laying on electricity like gas or water, charging the consumer only for what he used. With regard to another point which had been considered a great difficulty—the division of the current—Mr. Preece said it was not really a divided current, but that each lamp induced its own current. That did not seem to him a very happy mode of expressing it, and he would endeavor to explain it in another way. Each of the lamps they would see, was situated between two parallel wires, from which went two small wires, which were attached to the filament of carbon in the lamp. Now, if instead of electricity they supposed water were being used, and that the wires represented the pipes, and one pipe contained a pressure of water, while the other acted as a return pipe, there being no connection between the two except by small pipes, represented by the wires going to each lamp, as long as only one of these small pipes was opened, the quantity which would pass would be only as much as could be transmitted by the one small connecting pipe; if two were opened, there would be double the quantity, and so on. Assuming for the moment that none of the pipes were open, then having once established a pressure of water, it required no energy to maintain it, if there were no leaks. You could bring the pressure up to a 100 lbs. on the square inch, and if there were no leak it would continue for ever; but if you established a connection between the pressure pipe and the return pipe, and allowed one gallon per minute to flow away, you must exert as much energy as would supply one gallon per minute under a pressure of 100 lbs. Similarly, if you established a connection between one wire and another, which allowed a given amount of electricity to pass, you must employ as much energy as would develop electricity equal in quantity and tension to that which had passed away: if you had ten wires connected, you must develop ten times as much energy. So that it was not in truth a sub-division of the current, but was allowing the current to flow, and regulating the amount of power to be put on accordingly. It would be easy to ascertain, by an indicator at the central station, what the demands were, and determine what should be the amount of pressure, as it were, in the conductors, and the number of horse power required to be developed in the engine, in order to supply the pressure. Mr. Johnson gave as an illustration the governor at a gas works, which controlled the pressure in the mains, and which had to be varied, from time to time, according to the draft upon them. At this time of the year, probably at half-past three, there would be a rise of pressure of so many tenths, another rise at four, again at half-past four, and so on until you got to the time when the theaters and shops were all using gas; and then came the maximum, which would be maintained until ten, when there would be a slight reduction, and a further reduction at midnight, when the uniform night pressure would come on and be maintained until about six; and then perhaps the day pressure would come on, and be maintained until the afternoon. A gas manager plotted this out on a sheet of paper which was affixed to the instrument, and this drew on the same sheet of paper, a trace showing the amounts and the durations of the pressure actually given, by the governors, so that, according to the way in which the pencil followed the lines already laid down, the manager could judge of how his directions had been carried out. Thus, by looking at the paper, you could tell if there had been a foggy day. If the day pressure provided for was say $\frac{12}{10}$, and the implement showed there had been $\frac{20}{10}$, you would know that there had been a fog, that the paper had had to be disregarded, and extra pressure put on. As he understood, provision would be made in the same way for increasing the electric current when required. With respect to the arc and incandescent lights, they would all agree that no one could dogmatize on what would be the light of the future, the whole matter being, as yet, too much in the trial stage; but, at present, he thought all would prefer the incandescent light for domestic illumination. It was admitted that the arc light was much more economical, perhaps 10 to 1; Mr. Shoolbred said 8 to 1. Then Mr. Preece objected to the arc light being placed high up; but it was shown conclusively to the committee that sat on the lighting of Liverpool, that there really was no loss by placing the light high up. It was true the effect of the light diminished with the square of the distance, and that, therefore, a light a hundred feet up would give only one-hundredth part of the intensity of light that would be given by the same light if it were ten feet up; but, assuming an equal diverging angle for the really effective rays, it would, on the other hand, light a hundred times the area. The only difference, probably, would be the want of penetrating power in case of fogs.

The vote of thanks having been passed unanimously,

Mr. Preece, in reply, said it appeared that his sins had been rather of omission than commission, and this would be further explained by the opening paragraphs of his paper. It must also be remembered that that was the third or fourth time he had read a paper before the Society on electric lighting, and the sixth or seventh time he had spoken on the subject, and he had not, of course, again gone over ground he had already trodden. It would not be true to entitle his paper a description of the Edison light, as other matters were treated; but it was evident that what he had said about it, and what had been seen by the audience, had produced a very deep impression on their minds.

REPORTS ON THE SEWERS AND NOXIOUS SMELLS OF PARIS.

From "Le Genie Civil," for Abstracts of Institution of Civil Engineers.

The Commission appointed by the Prefecture of the Seine to inspect the sewers of Paris has issued two reports. The first treats of the sewers and the discharge of the waters, and the second deals with the methods of removing the bad smells by the various processes proposed.

The branchings off of the sewers have been found much fault with, as checking the flow and giving rise to bad smells, and they are defective in many places. The improvements proposed are a larger discharge of water, a continuous system of cleansing by keeping the bottom portion in constant motion by paddle boats or other means, and an enlargement of the culverts, especially at the junctions. The newest and largest sewers in Paris, along the Avenue de l'Opera, the Rue Richelieu, and the Rue Vivienne, are obstructed by water pipes, telegraph wires, &c., and consequently are difficult to cleanse. The section insisted on by the Commission as a minimum is a height of 6 feet 7 inches, and a breadth of 4 feet 3 inches. The injection of fecal and organic matters into the water-supplying sewers is strongly objected to; and it is urged that proper filters should be placed at the entrances to the sewers to retain all earth and sand which might tend to accumulate in the sewers and impede the flow.

The second report refers to the various chemical disinfectants which have been proposed, in addition to the main requirement of a much larger daily discharge of water through the sewers. All disinfectants act by means of their primary ingredients, consisting of either chlorine, sulphur, or nitrogen, producing by their decomposition in presence of moisture, hydrochloric, sulphuric, or nitric acid. Three special points were investigated, namely, disinfection, purification, and destruction of noxious germs.

In disinfecting, two substances have to be eliminated, namely, ammonia and its fatty aromatic compounds, and sulphuretted hydrogen. All acid compounds easily neutralize ammonia, which, moreover, is but little injurious, and the proposed disinfectants serve to remove it. Sulphuretted hydrogen is more difficult to deal with, especially in the cesspools, where it is present in large quantities; whilst in the sewers it decomposes rapidly in contact with the air, and seldom exists in them to any extent except when an unusual quantity of sewage has been discharged at one point. Mr. Madot's liquid, Mr. Charpentier's phenic sulphate of iron, Mr. Egasse's chloride of zinc, and Mr. Rafel's powder, serve to decompose it. The fatty and aromatic compounds of ammonia, which cause the worst smells, are more difficult to treat on account of their dangerous volatility. According to Mr. Huet, his disinfectant is able to prevent their generation by means of its antiseptic properties, but is powerless to stop their propagation when once generated. Mr. Grelle's English coal, in considerable quantities, is alone able to act upon them. Experiments are now being conducted on this subject.

Purification is a still more difficult problem, as not only have the waters to be disinfected, but the waters dirtied by the chemical products have also to be restored for consumption. From a series of experiments conducted by Messrs. Lévy and Allaire, it appears that the purification effected by each of the proposed disinfectants is very defective, the chloride of zinc and the Rafel powder alone producing admissible results; only a portion of the organic nitrogen in solution is precipitated, and the small germs are unaffected. The action of the disinfectants in purifying cesspools is more satisfactory; but the amount of organic nitrogen neutralized is not at all proportionate to the weight of disinfectant employed.

The germs must be destroyed by the use of antiseptics, such as alcohol, tar, tannin, salts of alumina, &c., or, the best of all antiseptics, cold. In a series of experiments on the action, in this respect, of the six disinfectants proposed, the phenic sulphate of iron proved the best for equal doses. Taking, however, the most effective result tried with a double dose, or 6¾ grains of Rafel powder to a gallon of water, which delayed the appearance of a germ for six days, it would cost £440,000 a year to apply this method to the 104,640,000 cubic yards of water annually discharged into the Seine from the Paris sewers. The operation of the disinfectants would accordingly, as regards germs, be expensive and incomplete, if not useless; and purification by means of the soil still presents the best solution of the problem. The report is summed up as follows:—the radical and complete solution to which one must strive to attain being still distant, the disinfectants, in spite of their insufficiency, still preserve their local value.

A NEW ELECTRICAL STORAGE BATTERY.

From "Nature."

The great utility of some thoroughly practical method of conserving electric force has caused a great deal of attention to be applied to the subject; no system of electric supply can be considered as perfect until some means is used to so store the force generated that it may be drawn off equally and regularly, and this whether the generator be on or off. If we take, as an example of electric supply, the present systems of electric lighting, it is at once seen, should an accident or stoppage take place in the machinery generating the current, the whole of the apparatus such as lamps or motor machines are influenced; should there be a reservoir of electricity between the generator and the apparatus of whatever sort for utilizing the force this inconvenience would not occur.

All the present systems of storing electricity depend on certain chemical changes produced by electrolysis.

I have gone through a long series of experiments on storing electricity and made many forms of cells, one being a porous pot containing dilute hydric sulphate and a sheet of lead, in an outer vessel containing a sheet of lead in solution of acetate of lead, the plate in the porous pot being made the positive electrode; this cell had the power of storing electricity, by peroxidizing the positive electrode, and depositing from the acetate of lead solution metallic lead on the negative electrode, the hydrogen having combined to form acetic acid. On discharging the peroxide is reduced, and the oxide formed during discharge on the other plate dissolves in the acetic acid, forming the original solution of acetate of lead; by this means I eliminated the injurious effects of the hydrogen on charging.

During my experiments I found that red oxide of lead is a very bad conductor of electricity, and the peroxide a good conductor. I also discovered that by amalgamating lead plates with mercury a marked increase was immediately manifest in polarization effects, the plates becoming more uniformly and rapidly peroxidized when used as positive electrodes, and local action entirely disappearing. These mercury-amalgamated plates at once gave me an advance of other cells. I used them in many ways, constructing cells in which the positive plate was amalgamated, and the negative coated with red oxide, or with peroxide, produced by treating red oxide with dilute hydric nitrate till the brown precipitate of peroxide fell, the precipitate being washed and painted on the electrode. I also amalgamated the negative electrode simply. I found that in every way positive electrodes amalgamated produced the best results. I also made cells in which either peroxide or red oxide was formed into a porous conglomerate, using the conglomerates as electrodes, immersed in dilute hydric sulphate. I constructed cells with parallel plates, red oxide or peroxide being filled in between the plates; in this experiment red oxide is useless and peroxide efficient. In all these experiments I succeeded in storing electricity to different extents.

Having thoroughly satisfied myself that positive electrodes amalgamated with mercury were the best, I investigated the behavior of various forms of negative electrode, having in view the conservation of the hydrogen; this I thought to do by occluding the hydrogen in suitable electrodes, as spongy platinum or metallic palladium; but as both these methods would be useless, owing to expense, I did not even experiment on them.

I further thought of having negative electrodes, whose oxides should be soluble in the solution, and which could be redeposited from the solution, or of having metallic solutions from which metal could be deposited, the resulting solution being such that should, on the oxidation of the deposited metal, combine with the oxide and again form the original solution.

I thought that success in this manner would result in a powerful and constant source of stored energy, the cell would not polarize itself during discharge, as is the case in both Plante and Faure cells; in these cells the peroxide formed by the discharge produces a contrary electro-motive force.

Experimenting from this train of thought, the results I have obtained are such as to have an important practical bearing on the future of electric work.

The experiments comprised amalgamated lead as a positive electrode with negative electrodes composed of either zinc, iron or copper, in each case the solution between the electrodes being a salt of the metal composing the negative electrode. With zinc, sulphate of zinc was the solution; with iron, sulphate of iron; and with copper, sulphate of copper. In all these cases the results were not only far more powerful than with any form of cell I had previously devised, but also very constant, the polarization lasting many times longer than in any other form of cell. The cell with zinc negative electrode I discarded, owing to the necessity there would be to keep the zinc plate amalgamated to prevent local action; the iron negative electrode was set aside owing to the iron oxidizing when the cell was not in use. The cell having a negative electrode of copper, a positive electrode of lead amalgamated with mercury and a solution of cupric sulphate, I have adopted as a thoroughly economical, lasting and practical form of storage reservoir. The chemical changes in this cell are exceedingly interesting and beautiful, the cell being composed of a sheet of lead cleaned with dilute sulphuric acid and amalgamated thoroughly with mercury, and a sheet of thin copper a little shorter; the two sheets are perforated with a number of holes and then rolled in a spiral, separated by rubber bands cut every five inches, the holes in plates and cuts in rubber bands being to allow free circulation of the solution (the short plate being uppermost before rolling). This combination is immersed in a solution of cupric sulphate, and the amalgamated lead plate made the positive electrode of a suitable source of electricity, the chemical action being that the oxygen of the decomposed solution combines with the lead, forming a perfectly even coating of the insoluble peroxide, the hydrogen replacing the copper of the solution, and the copper being deposited in the metallic state on the negative electrode. As the decomposition of the cupric sulphate proceeds the solution gradually loses its azure blue color, becoming more acid, and finally when the whole of the copper is deposited, we have the solution colorless and transformed into hydric sulphate and water, the positive electrode peroxidized and copper deposited on the negative electrode. During discharge the peroxide is reduced and the copper element oxidized, the oxide combining with the acid and forming cupric sulphate, the solution returning to its original color. This change of color forms a beautiful means of telling when the cell is charged; it is a veritable charging gauge. The power of this cell is very great and very constant; it can be made to last for hours, the time being dependent on the quantity of cupric sulphate decomposed.

I have, by the decomposition and recomposition of one pint of cupric sulphate, obtained over two hours' effective work in heating to a red heat one inch of No. 28 iron wire, the cell measuring internally 4 inches deep and 4 inches diameter.

I constructed cells with free crystals of cupric sulphate suspended in the solution, and found that the presence of free crystals prevented the oxidation of the amalgamated lead electrode, it being essential that the solution become slightly acid before the peroxide will form. The cell during charging gives out a peculiar rattling noise, which I consider due to the deposition of copper on the negative electrode altering the form of the spiral.

A practical form of cell for storing purposes ought to be made, by fixing a series of amalgamated lead plates in a box in grooves, as in Cruikshank's trough battery, filling the interval between the plates with solution of cupric sulphate, and passing a current through of sufficient tension to overcome the contrary electromotive force of the series, the positive sides of the plates being peroxidized and copper deposited on the negative sides. I have two boxes on this plan, each containing twenty-five plates, the total being equivalent to fifty cells. By this means batteries of great tension can be charged from thirty Bunsens. A number of twenty-five plate boxes can be coupled for quantity of charging, and for tension during discharge. Twenty such boxes, one foot square, internal measurement, will give in series a battery of 500 pairs of one foot square plates.

It will be seen from the foregoing that this method of conserving energy has a wide field before it, and as it will benefit fellow-workers in science, placing in their hands a means of experimenting with powerful electric currents, I give it without reservation, freely and untrammeled by patent rights, for their use.

THE PENETRATION OF SEWER GAS INTO DWELLINGS.

By Dr. LISSAUER, of Dantzic.

From "Deutsche Vierteljahrschrift für öffentliche Gesundheitspflege," for Abstracts of Institution of Civil Engineers.

The author states that, since the completion of the new drainage works of Dantzic, he has devoted much attention to the question of house connections and water traps. His general conclusion is that too little care is bestowed by the public upon these important matters, and that for various reasons the subject has been neglected. In all cases which have come under his notice the presence of sewer gas in dwelling houses has been due to obvious imperfections in the fittings, which were capable of being readily set right when once observed. Much ignorance concerning this subject prevails among all classes.

The author gives the results of ten experiments directed to ascertain the condition under which sewer gases may gain admission into dwellings, and the methods which may be adopted for their exclusion. He disclaims any attempt at chemical or morphological examination as being incapable in the present state of knowledge of leading to true results.

The following experiments were carried out in the house, No. 25 Heiligergeiststrasse, Dantzic, which was fitted up in entire accordance with the prevailing ideas. The soil pipe was prolonged and carried up through the roof, and received from the first and second floors a sink and a closet on each floor, a closet on the ground floor, and a closet and a sink in the basement. The observations were conducted in the ground floor closet, and for convenience of access the closet apparatus was removed, together with the water supply, leaving exposed only the siphon trap (of the form in common use). The diameter of the siphon was 11 centimeters (4.33 inches); the depth of water beneath the dip of the trap—*i. e.*, the minimum height of water to close the trap—was 8 centimetres (3.15 inches); or a total contents of 1,100 cubic centimeters (1.936 pint). In order to fill the siphon to the overflow level an additional level of depth of 1.5 centimeter (0.59 inch) was required, bringing up the total volume of water in the bend of the siphon to 1,450 cubic centimeters (2,553 pints). The actual water seal was thus 1.5 centimetre (0.59 inch) in depth. In the first experiment the trap was completely emptied with a siphon, and observations of the air currents were taken by means of a lighted wax taper, placed at the bottom of the trap. The direction of the flame readily indicated the nature of the current, the general direction being towards the soil pipe, showing that the sewer was sucking air. When water was poured into the soil pipe on the upper floors the flame was violently agitated and sometimes blown out. Water was then poured into the trap so as just to fill it to the full height of the seal, and colored black in order that it might be better observed. Frequent measurements were taken of the liquid in the trap (three or four times daily) for five days, during which time the water seal was diminished by suction into the soil pipe and evaporation to a level of —0.2* (—0.078 inch), showing the seal to have become broken. But on the first day, ten hours after the beginning of the experiments, air had forced up the blackened water over the top of the trap, the seal having become reduced to 0.7 centimeter (0.27 inch). Among the general conclusions from this set of experiments the author states that a seal of 1.5 centimeter had, after a five or ten hours' use, become insufficient for its purpose. In the second experiment a more complex trap, shown in an illustration, was employed, with a seal of 40 centimeters (1.31 foot). This apparatus became, under certain conditions an annular siphon,* and completely emptied the trap in a few seconds. The result of this experiment went to prove that the sudden emptying of a bucket of water on the upper floors produced such a compression in the lower part of the soil pipe as to correspond with a manometrical rise of from 1 centimeter to 2 centmeters (0.39 inch to 0.78 inch). The third set of experiments were carried out with another apparatus, shown in an illustration, and directed specially to ascertain and measure the small fluctuations in the pressure of the gases in the soil pipe. Arrangements were made to keep the water in the trap at a uniform level (*i.e.*, to restore all water drawn through the trap) by means of a double siphon connected with a store vessel containing a measured quantity of water. This store bottle the author names the "Restitutor." The result of this set of experiments proved that the water in the trap could easily be automatically maintained at one uniform level by a simple siphon apparatus. Further, that the suction down the soil pipe is such that on all ordinary occasions it represents a rise of from 0.1 centimeter to 0.2 centimeter (1.039 inch to 0.078 inch) in a manometer. On very stormy days this difference may at times rise to 0.6 centimeter (0.234 inch). The outward pressure from the soil pipe into the house caused by the use of the upper closets may correspond with a column of water from 1.6 centimeter to 2.2 centimeters (0.63 inch to 0.87 inch) in height.

In the fourth set of experiments a siphon trap was employed which had its front formed of glass, so that the height of the water on each side of the dip could be accurately observed, and measured by millimetric scales fixed in either

* That is, below the level of the dip of the siphon.

* By the same action as has been observed in Field's annular siphon and flush tank.

limb of the inverted siphon. The water employed was a soda solution, and strips of turmeric paper were suspended to show the height to which the water was blown up in the passage of gases through the seal. The depth of the seal was at first 2.5 centimeters (0.98 inch). Numerous tests were made of the seal by throwing down buckets of water in the upper closets, &c. This set of experiments proved that the utmost pressure of the gases did not exceed that of a column of water 2 centimeters (0.78 inch) in height. A seal of 2.5 centimeters (0.98 inch) was capable of resisting all pressure of gases in the soil pipe for five days, while the closets throughout the house were in ordinary use, and only gave way on the sixth day, when the seal had been reduced to 1.3 centimeter (0.51 inch). Nine buckets of water rapidly thrown down in the upper closets sufficed to break a seal of 2.5 centimeters.

The fifth experiment was conducted at 37, Jopengasse, with a similar apparatus to the last, but with a seal of 3 centimeters (1.18 inch). In this case an opening of 3 centimeters was made in the siphon so as to afford direct ventilation into the open air, and thus provide an escape for the confined gases other than by forcing the seal. By this means the pressure was so reduced that the utmost movement of the water in the trap was reduced to from 1 millimeter to 2 millimeters (0.039 inch to 0.078 inch). The sixth set of experiments was conducted with a sink trap, containing only 250 cubic centimeters (0.44 pint), and which required fifty-two days to become wholly exhausted; though in one week the level had fallen from 4.4 centimeters (1.74 inch to 3.1 centimeters (1.21 inch), and in eighteen days to 2.6 centimeters (1.02 inch). In the seventh set of observations a perforation was made in this trap to ventilate it, and sundry experiments with large volumes of water thrown down the closet were carried out. In the eighth set of experiments the water used in the trap was spring water, to see whether the absorption of sewer gas had anything to do with the rapidity with which the seal was forced. The result proved that *cœteris paribus* a trap was able to resist the passage of sewer gas the longer the water it contained required for its saturation with the gases. The next experiment was directed to prove the reverse of this axiom, and water saturated with carbonic acid gas was employed. In this case, after five buckets of water had been thrown down the soil pipe, the trap was forced; while it had required nineteen buckets of water to force a trap containing an equal volume of clear spring water. The tenth and last set of experiments were made on the same small sink trap, but provided with a "Restitutor," as in No. 3; and it was found that this apparatus enabled the water in this trap to be kept automaticcally at any required level.

The author next gives ten instances of faulty house connections and cases of illness connected therewith, and finishes with the recommendation that all domestic sanitary arrangements and apparatus should be placed under the control and subject to the inspection of the local authority. He advises the employment of a separate ventilating pipe alongside the soil pipe, carried up above the roof and placed in free communication with the open air, into which pipe all the traps are to be ventilated by openings, not less than 3 centimeters (1.18 inch) in diameter, situated between the water seal and the soil pipe. He speaks of the English system of disconnection at the foot of the soil pipe as unknown to him by practical experience, and as of little use in Dantzic, where the street sewers are so formed as to suck air (which is in itself a protection to the houses), and where pressure of gases, tending to force their way into dwellings, only occurs at intervals in the form of gusts (*stossweise*). He concludes by stating that in all new dwellings the authorities of Dantzic have made compulsory the plan he advocates of direct ventilation of the siphon trap.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA.—The meeting of December 3, 1881, was the first held in the new rooms. The matters of scientific interest presented, were as follows: Mr. John E. Codman exhibited drawings of and described Nicholson's Fire Escape, which consists of a fireproof brick tower, octagonal externally and cylindrical internally, with central shaft about 18 inches diameter, around which is formed a winding passage of a U-shaped section, 2 ft. 8 in. in width, with smooth or glazed surface, and inclined at an angle 35°, with retarding curves of less gradient. Fireproof doors would connect with each floor and roof, and a vestibule with the surface ground below. It is intended that those escaping shall assume a sitting posture on entering the spiral and slide to the bottom, and it is claimed to be safer than other escapes for those unaccustomed to ladders, or weakened by fright or excitement. Mr. Codman also exhibited a working model of Deschamp's Angular Shaft Coupler, by means of which shafting can be offsetted when bearings are displaced or bent to any angle, from 0° to 90°. Prof. L. M. Haupt exhibited an Interpolating Scale, devised by Prof. W. S. Chaplin, of University of Tokio, Japan, by means of which any intermediate point of elevation between two known points, on a topographical plane, can be readily determined. He also read a short discussion of Mr. S. C. Gant's scheme of Underground Railroads in Philadelphia, presented at last meeting. Prof. Haupt, while decidedly favoring rapid transit and admitting the practicability of the construction proposed, considers Mr. Gant's estimate entirely too low, and, by comparison with the Union Tunnel at Baltimore, he estimates that that portion of the tunnel system which Mr. Gant estimates at $1,733,710 would cost $6,051,500, or about three and one-half times the original estimate, and even this he considers too low for the plan proposed. Prof. Haupt also read a paper upon Railroad Crossties, touching especially upon the desirability of an iron tie, a model of which he exhibited at the last meeting. Mr. T. Earl Collins exhibited and described a model of the Camerer Valve Motion. Mr. Wilfred Lewis exhibited a moveable head T square, the head of which is held very firmly in position by means of a cone clutch.

DECEMBER 17th, 1881.

Mr. T. M. Cleemann exhibited photographs of and described several examples of ancient Roman masonry. He regarded as the most important and remarkable for its excellent pre servation, the aqueduct at Nismes, in the south of France, which was built at about the beginning of the Christain era, and represents the engineering skill of the Romans when their power was at its height. It consists of three tiers of arches, the two lower being similar and superposed on one another, the upper tier of much smaller dimensions, upon the top of which runs the water channel. The various arches differ in span—lacking the regularity and conformity to one pattern of modern works. The center line was likewise not perfectly true, showing that no transit had been used by the engineer in charge.

The approximate dimensions are as follows: largest arch, span 75 ft., piers 15 ft. (by Rankine's rule about 11½ ft.); ringstones 4ft. thick (Rankine, 2½ ft.); water channel, originally 6 ft. × 4 ft., rectangular, now reduced by calcareous deposit nearly 1 ft. thick. Bond of piers, alternate header and stretcher, in courses of about 18 inches.

In the lower tier the arch stones are laid in four, and in the middle tier in three rings, without bond; in the upper tier in two rings, breaking joint. Closely-laid rings, without bond, was also observed in a Roman bridge at Avignon.

Numerous stones projecting from intrados and face are supposed to have been left to support centers and scaffolding during construction. The whole structure seems to be founded on rock.

An aqueduct near Rome and the Basilica of Constantine were also described. The latter was built about A. D. 300, and consists of bold arches, 66 ft. span, of brick, one abutment of which is only about one-third of the radius of the arch, which is considerably thinner than Rankine's rule would require, but the use of old Roman cement has reduced the structure to almost a monolith.

Mr. Thomas C. McCollum contributed a block, cut from a pile which had been under water but three months near Pensacola, Fla., and, not having been creosoted, was completely honeycombed.

Prof. L. M. Haupt read a letter from Mr. Walter Shanly, C.E., upon the water transportation routes from the North-west to Europe.

ENGINEERING NOTES.

THE PANAMA CANAL.—A complete account has now been published of the proceedings of the superior consulting committee of the Panama Canal works, which assembled in Paris for its first session on November 25. A report drawn up by the consulting engineer, containing the proposals of the administrative council for the second phase of the work, was laid before the Commission, and served as the basis of its deliberations. It is considered that the best opening for the canal at its eastern end into the Bay of Simon, will be by way of the mouth of Folks' River. A cutting through the Mindi Hills would bring the canal from Folks' River to join the River Chagres, whose bed is also to be taken advantage of for a considerable distance; and it is proposed to begin it very soon, and make a sort of temporary canal for immediate use on the line of the great one, so as to establish water communication with Gatun, on the Chagres. The Administration asked permission to begin work at once at two points; upon the rocks between the falls of the Obispo, and at the highest point of the cuttings, the top of the Cerro Culebra, where, however, the soil is argillaceous. Here preliminary cuttings will be made, which will give more accurate knowledge of the nature of the ground than can be derived from any number of soundings. According as the earth is removed, it will first be piled up in banks to protect the cuttings from becoming drains for rain water, and then gradually be used for a tramway from the Culebra working to the Gamboa dam, to convey thither all the remaining débris. We have mentioned this dam before, and now need only add that owing to the great depth at which the solid rock lies at that spot, it has been decided not to attempt to make any foundation, but simply to heap the materials on the surface of the ground. A wall of great blocks of stone will cross the valley, inside and above it will be laid in order smaller blocks, rough stones, pebbles, gravel, sand, and clay, and the Culebra débris. Arrangements will be made to prevent flooding during the course of the work. The Commission assented (after deliberation) to these and all other proposals of the Administration, with a few slight qualifications.

THE ST. GOTHARD TUNNEL.—We have several times spoken of the difficulties with which M. Favre had to contend when he bebecame contractor against much opposition for the construction of this tunnel, and of the obstructiveness by which even some members of the St. Gothard Railway Company prevented his commencement and proper progress of the work. Since the tunnel has been drawing towards completion the company has several times commenced and threatened to commence proceedings against the executors of M. Favre on account of its non-completion to date. It is, however, completed long before the company's lines are ready to work it. The tunnel company has thus gained an unenviable notoriety; yet, according to the *Times* Geneva correspondent, the company is again commencing fresh proceedings against the executors of the late Louis Favre, the contractor, for the recovery of the penalties which it alleges he has incurred by exceeding the time originally fixed for the completion of the undertaking. "The company has even gone the length of confiscating some of the securities lodged with them as caution. Considering that, inasmuch as the lines of access are not yet finished, the company is in no way injured by the delay; that the delay is due rather to its *lâches* than any fault of Favre or his representatives; and that Favre lost the whole of his fortune by the contract, this proceeding is regarded as harsh and unfair in the extreme. The press is unanimous in denouncing the conduct of the company, and there is a general demand for the intervention of the Federal Council, who are empowered to settle all disputes arising out of the construction of the tunnel, to prevent the consummation of an injustice which would dishonor the whole country." According to official figures the cost of this tunnel from first to last has been 56,808,620f., or £2,272,344..

RAILWAY NOTES.

THE WESTINGHOUSE CONTINUOUS BRAKE.—It is about ten years since Mr. George Westinghouse first came over to this country with the object of inducing railway companies in this country and on the Continent to adopt his system of continuous air brake, which had at that time found a large and very useful application on the railways of the United States. At that time continuous brakes were only exceptionally used on English railways, and not at all on the Continent. Here the necessity for them was realized, but not so fully as a few years later, when the increase in the number of trains and the acceleration of speeds rendered some efficient means of controlling trains absolutely necessary. The Board of Trade took action in the matter by a series of exhaustive trials, and having satisfied themselves as to the requirements of an efficient brake, and also as what could be done within practical working limits, laid down a series of conditions sufficiently stringent, but capable of being fulfilled by one system—the Westinghouse automatic. This was a very considerable advance over the original Westinghouse continuous air brake, which was, however, until the introduction of the improved system, the most efficient that had been introduced. These trials took place in June, 1875, and were only one series of a large number carried out before and since both in this country and on the Continent, and which proved conclusively the superiority of the Westinghouse brake over all the other systems with which it came into competition. In spite of this undoubted superiority, the adoption of the automatic air brake proceeded but very slowly on English railways, owing to causes with which we need not trouble ourselves now. But however slow this progress, it has been at all events steady, and during the last two years has advanced with more rapid steps, while on the Continent the adoption of the Westinghouse automatic brake may be said, as regards France and Belgium, to be universal. An examination of the results obtained will show that Mr. Westinghouse has established his system in Europe on as strong a basis as in the United States. Up to the 25th of last month the number of automatic brakes in use or ordered for immediate application were as given in the following table :

Country.	Engines.	Carriages.
England	1,087	7,719
France............	1,416	7,193
Belgium...........	359	1,728
Germany	63	105
Austria	4	32
Russia	64	51
Holland...........	59	208
Italy......	11	35
Sweden	1	6
India	6	60
New South Wales.	66	124
South Australia....	27	18
Queensland	1	11
United States......	3,435	12,270
	6,599	29,560

In England the system is in use on fourteen different railways, the chief of which are the Northeastern, with 328 engines and 2343 carriages, the London, Brighton and South Coast Railway, with 256 engines and 2116 carriages, and the Great Eastern with 136 engines and 1,064 carriages The North British, the Caledonian and the Glasgow and Southwestern also have their stock fitted with the brake. In France the system may be said to be universally adopted, since it is the standard brake on the Western, Ceinture, the Paris Lyons and Mediterranean ; the Orleans and Midi have accepted it. The State railways of France have not yet definitely decided, and the Northern, which for some time has employed the vacuum brake, has still that system in use. There is little doubt, however, that with a uniform system throughout the other railways, the Northern will soon decide on making a change. In Belgium, on the whole réseau of State railways, the Westinghouse automatic brake is used, it having been very early adopted by the Government, which has every reason to be satisfied with the wisdom of their selection. In the United States it is of course recognized as the standard system, no less than 190 railway companies employing it As regards the non-automatic or early continuous brake, its use continues to a large extent in America, there being in service on United States lines, 2,579 gines and 11,389 cars fitted, while in England and the colonies there are 58 engines and 399 carriages running with the brakes. Thus the total of railway stock to which Westinghouse brakes have been applied and are to-day in use amount to no less than 9,236 engines and 41,349 carriages. These figures are more conclusive than any argument could be, of the acknowledged efficiency of the system. Despite the hesitation, indifference, and in some cases obstructiveness of locomotive superintendents in this country, the example set by Belgium and France (in both of which countries the automatic brake was promptly decided upon), will doubtless be followed here as soon as public and official pressure enforces general action. The Westinghouse Brake Company, Limited, employs more than 500 men manufacturing automatic brake apparatus in their various establishments in Europe, the present capacity for turning out work being equal to 1,200 carriages and a proportionate number of locomotives per month.

M. Papon, a deputy for the department of the Eure, has introduced into the Chamber of Deputies a bill for the immediate purchase of the whole of the French railways by the Government. The scheme provides for the division of the great lines into sections of 2500 kilometers, each of which is to be managed by a company under the general supervision of the Minstry of Public Works. M. Papon's proposal is already meeting with considerable opposition, as it ought.

The Marseilles correspondent of the *Daily News* writes that several Frenchmen, living at Sfax, in Tunis, have formed themselves into a committee, under the presidency of Dr. Fernand Laffite, with the intention of carrying out the suggested railway across the Sahara. A superior commission has been appointed to examine the means of uniting the Senegal with the Niger, and Algiers with Timbucktoo, by railway, and of uniting by a combination of railways the two large African colonies. However, the Trans-Sahara Railway will give access only to a very limited part of the Soudan.

The Midland Railway has refused, it is said, to carry the new big bell for St. Paul's from Loughborough to London, on account of its weight exceeding the carrying powers of any of their trucks. *Colonies and India* thinks that the directors of this and other English railways might take a hint from the "cars" employed on the Canadian railways, where a "new combination box-car" has lately been introduced which will carry 30 tons of freight. It lately took a load of 9,800 bushels of wheat, weighing 48,000 lbs., the whole of which was unloaded in one minute; after which it carried 16,080 ft. of green lumber, weighing 70,000 lbs., in one journey; and followed this up by taking the enormous load of 1000 bushels of barley.

An American company is making proposals to the Transvaal Government to construct the Delagoa Bay Railway. It is reported, says the *Colonies and India*, that England has offered to give the telegraph line to the local Government.

From the report on a recent accident on the English Great Western Railway it appears that it is considered safe to work the block system with a much less margin of safety than is considered necessary upon many other lines. Under their regulations "line clear" without any reservation or caution can be given when there is an obstruction on the line a certain distance, specified in each separate case, inside the home signal, which distance in the case of Ely was 107 yards. Upon some lines, in such a case, the line would have been blocked, and on others the train would have been allowed to move forward only with a caution. As at present worked, the block regulations upon this line do not sufficiently provide for the safety of the public.

This winter two new State lines are to be commended in India, both as protective works against famine. The first is the meter guage line, from Rewari on the Rajpootana Railway—and extending to Hissar. It will be carried on ultimately to Ferozepore, and when finished will greatly shorten the communications between the Punjab and Bombay. The second line, also of the meter guage, will connect Bellary with Goa and the Murmagao Railway, and will have a branch from Gadac to Sholapore, on the Great Indian Peninsula line.

Surveys are shortly to be commenced of the three alternative routes between Calcutta and Nandgaon, the present terminus of the Nagpore-Chatisgarh Railway, and and the long-talked-of direct Calcutta and Bombay Railway may shortly become an accomplished fact. Another survey party will examine the country between Mymensing and Gowhatty, in Assam. The country north of the Ganges, from a point opposite Patna to Baraitch, through Goruckpore, is also to be explored, and it is rumored that if the Government decides on a railway there, its construction will be entrusted to private enterprise. There is also talk, says *The Colonies and India*, of surveying for a line to connect Bundelcund with the Central Provinces system.

Railway traffic in Germany and Austria has this year been increasing so generally as to leave no doubt as to the revival of business in those countries, the statistics include the nine months ending September last. On the main lines, State as well as private, of Germany, the increase was at the rate of 8¼ per cent. On the lines running through Austria and Hungary the increase was 6 per cent.; but the mileage of these lines had also extended 6.9 per cent. The purely Austrian railways showed an increase of 4 per cent., while the length of mileage was extended 2.9 per cent. The earnings of the purely Hungarian lines showed an increase of 5 per cent., while the mileage increased 3.9 per cent.

Of the 969 tires which failed on British railways during the nine months ending 30th September, 50 were engine tires, 82 were tender tires, 6 were carriage tires, 44 were van tires, and 837 were wagon tires; of the wagons, 684 belonged to owners other than the railway companies; 739 tires were made of iron and 230 of steel; 33 of the tires were fastened to their wheels by Gibson's patent method, 19 by Beattie's patent, 12 by Mansell's patent, 34 by Drummond's patent, all of which remained on their wheels when they failed; 852 tires were fastened to their wheels by bolts or rivets, of which 5 left their wheels when they failed; 19 tires were secured to their wheels by various other methods, none of which left their wheels; 153 tires broke at rivet holes, 224 in the solid, 6 at the weld, and 616 split longitudinally or bulged.

At the commencement of last year there were, according to official reports, 5112 miles of railway in operation in Italy, with 1492 locomotives, 4544 passenger cars, and 24,098 freight cars for equipment. Their average earnings per mile, in 1879, were £1,232 per mile, the working expenses £756, leaving as net earnings, £476, which is at the rate of 2.5 per cent., nearly, on the capital invested. The earnings from passengers were very nearly as great as the ordinary freight earnings, but a very large amount—nearly an eighth of the total earnings—was from the express and other freight carried on passenger trains; and there were on this system of less than 6000 miles, in the course of the year, 256 collisions and 400 derailments of trains, by which twenty-nine persons were killed and 439 injured.

ORDNANCE AND NAVAL.

Torpedo Boat Trial.—A trial trip took place a few days ago near Dantzig, with a new torpedo boat, built for the German Admiralty, and engined by Mr. T. Schichau, of Elbing, Prussia. The contract under which these engines were built, specified that with a total weight of 9900 lbs. for engine and boiler, inclusive of water, the engine should indicate 100 horse power. This performance was, however, by far exceeded at the trial, the engine indicating during a trial trip of five hours, 170 horse power, while the total weight amounted to only 9880 lbs., or 58.2 lbs. per indicated horse power. The performance was in every way highly satisfactory. The engines of the compound type have cylinders of 9¼ in. and 17¼ in., with 17¼ in. stroke, and work at a speed of from 400 to 440 revolutions per minute, diagrams being taken during the trial with one of Schaffer and Budenburg's high speed indicators. We hope on a future occasion to have more to say about these engines, which possess several striking features, and we also hope to be able to show some indicator diagrams obtained from them.

We are informed that Sir William Palliser is of opinion, from his many tests to destruction of his converted guns, that the injury to a Spanish gun by a violent pressure set up in the bore, bulging the tube so much as to crack the casing above and below longitudinally, and thus, as usual when this happens, according to his experience, separating the body of the gun from the breech, the latter being blown to the rear. Sir William has written to the Spanish Minister in London to ask that full information may be afforded to him on the subject.

Further information has reached this country concerning Ericsson's torpedo boat, the Destroyer. It appears that he has abandoned the use of steam for ejecting his torpedo from the boat, and uses gunpowder instead. Thus the boat really carries a submarine breech-loading gun. The target referred to in *The Engineer*, for November 18th, was made of Manila rope and wooden slats. A dummy projectile, or one of wood only, was discharged from the gun. The muzzle of the gun was 6½ ft. below the surface of the water. The charge was 12 lbs. of giant powder. The projectile was 25½ ft. long. The gun is aimed and discharged by electricity, operated by the steersman. The projectile traversed the target at a depth of 5 ft. beneath the surface of the water, appeared on the surface about 100 ft. beyond, and continued its course with considerable velocity for 200 ft. more. A submarine distance of 400 ft. was made in three seconds, although the gun charge was, as we have said, but 12 lbs.

IRON AND STEEL NOTES.

Steel for Magnets.—At the Society of Telegraph Engineers on Thursday week, Mr. Stroh drew attention to the fact that it was difficult to get good steel in this country for the manufacture of magnets. Two pieces cut from the same bar gave different results. In France, on the other hand, he found that very powerful magnets of reliable quality were made from the cast steel of MM. Charrière and Co. The superior power of the Gower-Bell telephone was largely due to the use of French steel. If good steel were used Mr. Stroh had found that the mode of magnetizing did not matter. Mr. Le Neve Foster, in reply to Mr. Stroh, said that he had used French steel at Silvertown for over a year, and that its excellent magnetic property was due to its containing some three per cent. of tungsten.—*Engineering.*

BOOK NOTICES.

Adolph Strecker's Short Text-Book of Organic Chemistry. By Dr. Johannes Wislicennes. Translated and edited by N. H. Hodgkinson, Ph. D. and A. J. Greenaway. London.

It is only in view of the fact that the subject is limitless, and even the list of its topics endless, that this treatise is termed a short Text-Book. Over seven hundred and fifty royal octavo pages of closely printed matter, with a few cuts, are employed in exhibiting the shortness of this essay.

No chemist, however, we presume, will be deterred from securing the book, if he has any need of the knowledge of recent discoveries in this department of research, nor will he hesitate to accept the book as an authority.

The molecular constitution of organic compounds, together with their physical properties and the theory of the formation of their derivatives, are more fully presented than the details of the processes of manufacture.

A Treatise on Chemistry—Vol. 3. Part 1—Organic Chemistry. By H. E. Roscoe, F.R.S., and C. Schoolemmer, F.R.S. New York: Appleton & Company.

The first two volumes of this fine work are already well known to chemical students. The present volume will, doubtless, prove equal to the expectations raised by the former. As the title page indicates, the work is not yet complete, and the real extent of volume three can hardly be foretold at present.

Certain of the subjects may, however, be assumed to be finished in Part I, and these are of great interest and value to all students of chemistry. We refer chiefly to the description of the processes of organic analysis as devised by the prominent analysts. The determination of vapor densities and of the molecular formulæ are also of especial value.

Aside from the above subjects, which are beautifully illustrated, the remainder of this volume is mostly devoted to the hydro-carbons and their deriva ives.

The volume contains 724 pages.

The System of Calculating Diameter, Circumference, Area, and Squaring the Circle, Together with Interest and Miscellaneous Tables. By James Morton. Philadelphia: Published by the Author.

This book is not quite as bad as its title would seem to indicate. Although the useful parts can hardly prove serviceable to the novice who may need them, by reason of the rubbish which obscures them, or the curious scraps of misinformation with which the substantial parts of the book are interpolated.

It does not, however, require much discrimination to detect the original portions of the book. These should be carefully omitted by the learner. As for the remaining portions consisting of tabular matter, they are obtainable in cheap form in school books and pocket table-books everywhere.

Only an inordinate fondness for mere arithmetical computation, especially for fifteen-place decimals could have prompted the writing of this book.

The Actual Pressure of Earthwork. By Benjamin Baker, M. I. C. E. Van Nostrand's Science Series, No. 56. New York: D. Van Nostrand. Price, 50 Cents.

This little book contains one of the most valuable of the practical essays of the Institution of Civil Engineers. Written by an engineer of large experience and with a thorough knowledge of the literature of the subject, the paper is of great value to all who are likely to be confronted with the problem of a high retaining wall.

Engineers who dissent from Mr. Baker's view in regard to the theory of earth pressure, will still find much of value in the book, in the examples cited, of walls that have stood or failed in apparent contradiction of the accepted rules.

In connection with this view of the work, Prof. Cain's article in this present issue of the magazine may be read with profit.

The price of the work we don't know; whatever it is, it is too much.

MISCELLANEOUS.

The Jablochkoff Electric Light.—A portion of the Bon Marché at Brixton was illuminated with the Jablochkoff electric light, and the installation will probably be followed by an extension over the whole building. This system of lighting has had a long and successful career in a number of industrial establishments in this country, among which we may mention Messrs. Shoolbred & Co., who commenced its use three years ago with forty lights, now to be increased to sixty; Messrs. Nicols & Son since 1879, and Mr. W. Whiteley during the last twelve months. All of these gentlemen speak enthusiastically (after their prolonged experience) of the superiority of the arc light over gas, and it is an important fact that after three years' work, the generators and lamp at Messrs. Shoolbred are in as good a condition as when they were first started. The Société Générale d'Electricité have now lighted the Thames Embankment since the 16th of December, 1878, and during that time there has been no suspension of the light through any failure of the system, the only periods when it was not used being during alteration involved from extension of the company's contracts with the Board of Works.—*Engineering.*

Refrigerated Meat from Melbourne.—Some interesting information has just been received in Glasgow from Melbourne regarding the new industry in shipping refrigerated fresh meat to the mother country, an industry which may be said to have been originated by Messrs. John Bell & Sons, of Glasgow, a firm of merchant butchers. The correspondent, writing on the 25th of October, says that the steamer "Europa" had nearly finished taking on board 8,000 sheep and 500 lambs. No beef was to be sent, as large cattle was too high in price. The "Europa" had also a quantity of butter and a large shipment of wool on board. She had been fitted with a freezing machine constructed, the correspondent says, on an entirely new principle. It was made on the banks of the Yarra at Melbourne, and is worked by two steam engines of 20 horse power combined, and has three compressing cylinders and three expanding cylinders. The engineer having the shipment in charge (Mr. Hilliard) had expressed the utmost confidence in taking the meat to London in prime condition. The meat had been prepared at Maribyrnong, near Melbourne, and was shipped by the Australian Frozen Meat Preserving Company, at whose works there is in use a machine similar to the one fitted on board the "Europa."—*Engineering.*

The Use of Paraffin Compounds for Electrical Insulation.—In the course of our notices on the Exhibition of Electricity at Paris, we ventured to point out that the magnificent collection of electrical apparatus in the Palais l'Industrie, besides introducing to the general public a certain number of new applications of electrical science, would also display as novelties many reinventions of old discoveries, and many visitors to the Exhibition must have recognized in walking through the galleries several old friends in new dresses, and still oftener with new names. This was especially the case in connection with electric lamps, many of which bearing widely different names, possessing such strongly marked family likeness, that their descent from a common ancestor was obvious. And the same remark is applicable in a somewhat less degree to several of the dynamo electric machines which were exhibited at Paris. In another department of electric science, also, history (as evidenced by the Paris Exhibition) has a strong tendency to repeat itself. In a recent article we described the very interesting exhibits of Messrs. W. T. Henley & Co., and of MM. Berthould, Borel, and Cie., in the former of which an insulating material is introduced composed of a mixture of solid paraffin and india rubber, and in the latter an insulating substance is employed, which is compounded of paraffin and resin, while in another part Messrs. Latimer Clark, Muirhead & Co. exhibited a new compound insulating material to which the name "nigrite" has been given, and which is a mixture of india-rubber and ozokerit. In connection with these inventions it is an interesting historical fact that as far back as the year 1865, Professor Abel, C.B., the eminent director of the laboratories of the Royal Arsenal at Woolwich, not only conceived the idea, but took out a patent for insulating materials for electrical purposes, consisting of compounds of india rubber with paraffin or beeswax, stearine, spermaceti, or other solid fatty substances, or mixtures thereof, as well as of gutta-percha, treated in the same way, and in his published specification, Professor Abel describes methods of preparing the mixtures, as well as of covering electrical conductors with it, and there can be no doubt that the publication of this invention seventeen years ago has in the light of recent improvements become of considerable historical interest. Another point of interest is the fact that almost all the submarine electric cables that have been constructed are but little more than perfected modifications of the first submarine cable that was ever laid, namely, that designed by Mr. T. R. Crampton, C.E., and laid by him between Dover and Calais in the year 1851, and in the Exhibition specimens of this cable were to be seen, exhibited side by side with the splendid collection of specimens of cables made by the Telegraph Construction and Maintenance Company, and which have already laid the foundation for a network which bids fair to cover the whole civilized world.—*Engineering.*

M. Maiche has found by experiment that sounds from two separate sources can be sent and received simultaneously on one wire. He uses at the receiving station two telephones of different resistances, and at the transmitting station caused a musical box to be set going on a microphone of small resistance, whilst an induction telephone transmitter was spoken into at the same time. The musical sounds were reproduced in the telephone which had the least resistance, and the vocal sounds in the other, so that with the two telephones to the ears the music could be heard by one ear and the speech by the other.

At a recent meeting of the Academie des Sciénćes a paper was read by M. Lévy on the numerical application of the theory of maximum yield of two dynamo-electric machines employed for the transmission of power. Referring to a case discussed by M. Deprez, he shows that, by adopting different resistances, he would obtain 10-horse power at 50 kilometers, with a maximum electromotive force of 5,356 volts, instead of about 7,000.

The dry distillation of wood and the utilization and refining of the products appear to be making great headway in Germany. The manufacture of aniline requires large quantities of wood alcohol, which is now purified much more cheaply and better than hitherto. Acetic acid is now made of a quality not alone sufficient for technical purposes but for table use. The charcoal is compressed into cylindrical blocks weighing about one-tenth of a pound. They are largely used, a contemporary says, for domestic purposes, as they burn without smoke.

An autodynamic watch or clock has, it is said, been made by Mr. Frederick Ritter, Loessl. It is placed in a closed box, and does not require winding up nor to be moved, no external action being required to keep it going continuously. The watch is kept in motion by variations in atmospheric tension. The motor contains neither mercury nor any other liquid, all the parts of the watch being of solid metal. The watchwork is put in movement by a heavy weight, which remains always the same, and is appended to a roller. The function of the motor is then to provide that this weight, which acts as an accumulator, be kept constantly at the required height. The chain which carries the weight roller is a closed chain, and goes on one side through the watchwork, on the other through a winding-up apparatus, which is regulated by the motor. A compensation pendulum is employed to secure regularity.

The following are the resolutions relating to electrical standards adopted by the International Congress of Electricians at the sitting of September 22d, 1881:—(1) For electrical measurements, the fundamental units, the centimeter—for length—the gramme—for mass—and the second—for time—are adopted. (2) The ohm and the volt—for practical measures of resistance and of electromotive force or potential—are to keep their existing definitions; 10^9 for the ohm, and 10^8 for the volt. (3) The ohm is to be represented by a column of mercury of a square millimeter section at the temperature of zero Centigrade. (4) An international commission is to be appointed to determine, for practical purposes, by fresh experiments, the length of a column of mercury of a square millimeter section which is to represent the ohm. (5) The current produced by a volt through an ohm is to be called an Ampere. (6) The quantity of electricity given by an Ampere in a second is to be called a Coulomb. (7) The capacity defined by the condition that a Colcomb charges it to the potential of a volt is to be called a Farad. The adoption of these units for international use is to be preceded by a new and more careful redetermination of the ohm at the hands of the great physicists of all nations. And it is intended that this redetermination shall result in a standard for general adoption. Thus, remarks the president of the Royal Society, electricity will be the first of the practical sciences to be freed from all difficulties due to local standards; and it is to be hoped that this example may be followed in other sciences concerned with practical life.

In consequence of the burning of a car during the autumn of 1879, on one of the railways of Baden, which was suspected to have been caused by nitric acid, Professor R. Haas, of Carlsruhe, was called upon by the Government to report whether the acid could produce combustion or not. In the experiments made to solve this question, the conditions which might be supposed to exist in freight cars containing nitric acid were imitated as far as possible. Small boxes of a capacity of ten to sixteen quarts were charged with variable proportions of hay, straw, tow, and blotting paper —all of which substances are used in packing—and placed within larger boxes, while the space between them was filled with hay or tow, to prevent too rapid a radiation of heat, because the experiments were to be conducted in the open air, and the outer box at the same time represented the walls of a railway car. The material contained in the inner box was now saturated with acid, and rather tightly compressed, so that when the cover was put on it was pretty well filled. At first reddish and afterwards whitish vapors were given off, finally a distinct smoke. On lifting the cover strongly glowing patches could be seen, which rapidly increased all through the contents, and which broke out in bright flames on access of free air or gentle fanning. With red fuming acid, or with acid of specific gravity 1.48, these results were obtained very rapidly, and within a few minutes. With ordinary acid of specific gravity 1.395, it required somewhat more time, and the action was less energetic in the beginning; but, in three different trials, after about twenty minutes, the same result was finally obtained, provided, the *Analyst* says, that the material was packed tightly in the box, and was thoroughly saturated in its successive layers.

Glycerine, with a few drops of alcohol, is better than most oils for oilstones. For sharpening very small tools, such as gravers, nearly all glycerine, or glycerine with the addition of but a few drops of alcohol, is best.

It has long been taught that humid air acts as a conductor of electricity. Recent experiments of M. Marangoni throw doubt on this, for he finds that a Leyden jar heated so as to prevent condensation of moisture on its glass walls and thus arrest surface conduction, gives as long a spark as in the driest air. When, however, the precaution of heating the walls of the jar is not taken, the moisture condenses on the latter, and forming a thin film of water, causes a silent discharge which might be mistaken for a slow discharge through the conducting air.

The addition of kerosene oil will greatly assist in preventing sperm oil from gumming. *Calvert's Mechanics' Almanac* says:—"Thoroughly mix 100 parts oil with 4 parts chloride of lime and 12 of water. Now add a small quantity of the decoction of oak bark, to destroy all traces of gelatinous matter still remaining, and allow the impurities to settle. Next, agitate the clear part with a little sulphuric acid, settle once more and wash to remove the acid, which should never be permitted to exist in any oil used on machinery. If oil becomes rancid, boil it along with water and a little bicarbonate of magnesia for fifteen minutes or so, until it loses its power to redden litmus paper."

Mr. Henry Hussey Vivian has found that the one-thousandth part of antimony converts first-rate best selected copper into the worst conceivable, so bad as to be only fit for brass, and that one four-thousandth part makes it unfit for anything but inferior brass purposes and below the quality known as tough ingots. He discovered that one eight-thousandth part reduces it from "best selected" to "tough ingot" quality, and that one sixteenth-thousandth sensibly deteriorates the copper. Mr. Vivian states that one-thousandth part of nickel, cobalt, bismuth, arsenic, or phosphorus reduces "best selected" to "tough ingot," while nickel and arsenic in combination and mixed in the proportion of one five-hundredth makes copper unfit for brass, thus showing that two substances in combination may produce a far more hurtful effect than either of them separately.

The following recipes for coppering and bronzing zinc are said to produce very good results:—Prepare a solution of 15 parts of blue vitriol and one of 19 parts of cyanide of potassium, then mix both solutions together. Incorporate this liquid well with 160 parts of pipe clay, and rub the resulting semi-fluid mass, by means of a linen rag, on the previously cleaned object. For bronzing, take 15 parts of verdigris, 19 of cream of tartar, and 30 parts of crystallized soda, reduce them to powder, and dissolve them in the necessary amount of water. Mix this liquid together with 160 parts of pipe clay, and then proceed as above directed. Another process is as follows:—Take 15 grammes of blue vitriol, 20 of calcined soda, and mix them well with 32 cubic centimeters of glycerine, and mix the paste obtained with 80 grammes of pipe clay. It is then ready to be applied as before stated.

A simple form of photometric balance has been invented by M. Coulon, who calls it an *a thermanous* photometer, as being acted on only by luminous rays. Its principle is that a radiometer, whose temperature is constant, turns solely under the influence of light. The apparatus consists of a radiometer bulb fixed in the middle of a cube-shaped metallic case, having four lateral apertures, closed with glass, through two of which light can be sent horizontally, traversing the bulb while the two others allow observation of the bulb. The case is filled with water, which, through four vertical tubes, screened from the bulb, and surmounting spirit lamps, is heated to a temperature above that of the radiant heat of the sources to be measured—in practice about 100 degrees suffices. The bulb contains, *in vacuo*, a disc movable round a vertical axis; the half disc on one side of this axis being black on its two faces, the other white. When a single source of light acts on the bulb from one side, it attracts the white half and repels the black, so that the disc turns edgewise to the light, and presents one side to the observer. If another equal light act simultaneously on the other side and at the same distance as the first, the counteraction results in the disc presenting its sides to the light, its edge to the observer. Where unequal lights are compared, one may always, by shifting one of them, bring the disc into the second position just specified, and by then measuring the distances, ascertain the ratio of the intensities.

In a report on riveting in locomotive boiler works, made by a committee of the American Master Car Builders' Association, we find the following. The operation of "driving" rivets consists in placing a set on the end of the rivet, and sledging it down to form the head, the operation requiring two men to sledge, one to hold the set, one to manage the holder, and a boy to heat the rivets. "The rivet is not struck direct by the sledges at any time during the operation of driving, but the head is formed entirely by driving the set down squarely on the end of it. To drive a rivet requires about twenty-four blows with the 9 lb. or 10 lb. sledges at the rate of about eighty blows per minute; a flatter, with a face about 1¼ in. square, is then placed on the lap alongside the rivet, and given five or six blows to close the sheets together; the set is then placed on the rivet head again, and given five or six more blows and the rivet is finished; the whole operation of driving requiring about thirty-five seconds of time to the rivet. In practice we find that a riveting gang will drive in the seams of the shell of a boiler, on an average of thirty rivets per hour, or 300 per day, and in the seams of the fire box, in throat and back sheets, dome, mud ring, braces, &c., an average of about twenty-two rivets per hour. This includes the time necessary for taking out bolts, drifting holes, adjusting the tools and the work. In hand riveting two riveters will drive, on an average, taking the whole boiler, only about 125 rivets per day, or 12½ per hour."

The phenomena of the bursting of bubbles has recently occupied the attention of M. Plateau. When a bubble bursts it disappears almost instantaneously, leaving behind it a multitude of small liquid drops. The order of the phenomena is described as follows: The bubble begins to burst at one point, the film rolling away in a circle around the opening, and its edge becoming a rapidly-enlarging liquid ring. This ring draws itself together into segmental portions, which ultimately become small spherules. At the same time the contraction of the rest of the bubble causes a rush of air through the aperture, and blows off the spherules into the air with a kind of small explosion. The phenomena are best observed by blowing a bubble of glyceric solution upon an iron wire ring, and then bursting it at the top by touching it with a needle whose point has been dipped in oil.

At the meeting of the Chemical Society on the 15th inst., Mr. V. H. Vetey read a paper "On Some Higher Oxides of Manganese and their Hydrates." The author prepared pure oxides of manganese containing less than 1 per 1000 of potassium and 1 per 6800 of calcium. He heated the higher oxides in currents of nitrogen and in pure hydrogen, estimating the water evolved and the loss of weight of the oxide. The temperatures used varied between 80 to 200; a few experiments were made at higher temperatures. At certain points in the thermometric scale the manganese compound remained unaltered on continued heating at that temperature. On this ground the author concludes that a definite oxide or hydrate was formed. On raising the temperature a further loss of water or oxygen takes place, until another point in the thermometric scale is reached, at which the manganese compound again remains unaltered on continued heating at that temperature. The author concludes that another definite oxide or hydrate is formed, and so on. The author determined the specific gravity of some of these oxides. He concludes with some theoretical discussion as to the probability of the metallic oxides having formulæ much more complicated than those usually assigned to them.

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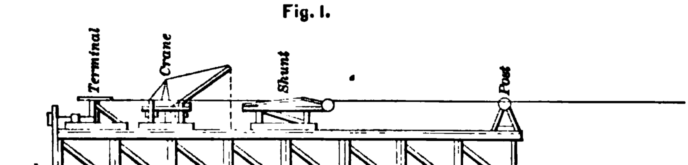
THREE SYSTEMS OF WIRE-ROPE TRANSPORT.

By WILLIAM THOMAS HENNEY CARRINGTON, Assoc. M. Inst. C.E.

From Selected Papers of the Institution of Civil Engineers.

The author proposes to describe three systems of wire-rope transport, each of which he has successfully applied on many occasions. The examples, hereafter referred to in detail, are those which in his opinion will give the best idea of the applicability and capabilities of each system. They are:—

Fig. I.



ELEVATION OF STAGING AT STORE END.

(1) An example of the single running rope system, invented by Mr. Charles Hodgson, with improvements by the author.

(2) An example of the double fixed rope system, worked on the gravitation plan.

(3) An example of the single fixed rope system.

A fourth system, of two fixed ropes, has been described in the minutes of Proceedings, by Mr. Churchward, Assoc. M. Inst. C.E., in a paper on the Monte Penna Wire Ropeway, lately erected by him from the author's designs.

It is believed the following details will show, that the several systems of wire-rope transport will form a useful and economical means of moving materials in situations where a railway or a road would be too costly or impracticable.

RUNNING ROPE SYSTEM.

The example of the single running rope system selected for description is that of a line erected in the cape de Verd Islands, at Messrs. Cory Brothers and Company's coal depot,, shown in Figs. 1, 2 and 3. Its total length is 500 yards, of which length about 320 yards extend along the beach, and about 80 yards at right angles to the longer section to the end of a pier, where the coal is received and despatched. The ropeway was required to be able to carry 15 tons of coal per hour in either direction, and the motion of the rope was to be utilized in working cranes at each terminal for raising or lowering coal. The coal is brought to the pier, in bulk, in barges from the colliers, and the buckets of the wire ropeway are lowered into the barges by a crane, and when filled are again raised and sent off on the ropeway to the depot, at its further end, where a quantity of about 10,000 tons is usually stored. To supply the steamers calling at the island the coal is filled at the store into bags holding 2 cwt., raised by a crane to the level of the wire ropeway, and carried by it back to the barges at the end of the pier.

The driving gear with its steam engine is placed at the point where the two sections of the wire ropeway meet at right angles. It consists of a massive wooden frame, carrying an upright shaft fitted at its upper end with two drums 8 feet in diameter, lying one on the top of the other, the ropes of the sections passing round these two drums, and being driven by them. At the lower end of the vertical shaft bevel gear is fixed, by which the motion of the steam engine is communicated to the drums. The usual shunt rails allow the loads to pass round the angle thus formed.

The steam engine is of 16 HP. nominal, has two cylinders, and is fitted with a surface condenser, it being impossible to obtain any fresh water for the boiler in the island except by distillation. The boiler is of the ordinary horizontal multitubular type, cylindrical throughout; it is worked up to a pressure of 60 lbs. The terminal at the end of the shorter section on the pier head carries the horizontal drum round which the tramway rope passes, and a long horseshoe-shaped rail. On this frame is also mounted a crane, having a radius of 17 feet, and worked by shafting from the engine. This crane is manipulated by a friction clutch, actuated by a lever on the top of the frame, on which the man stands and has a clear view of the work going on

Fig. 2.

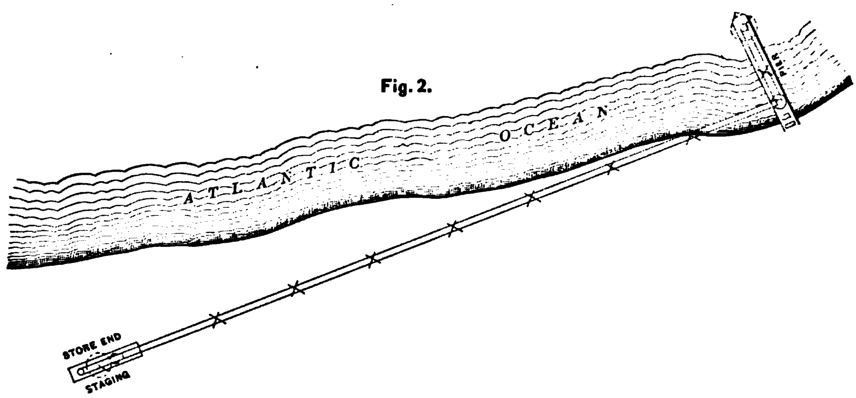
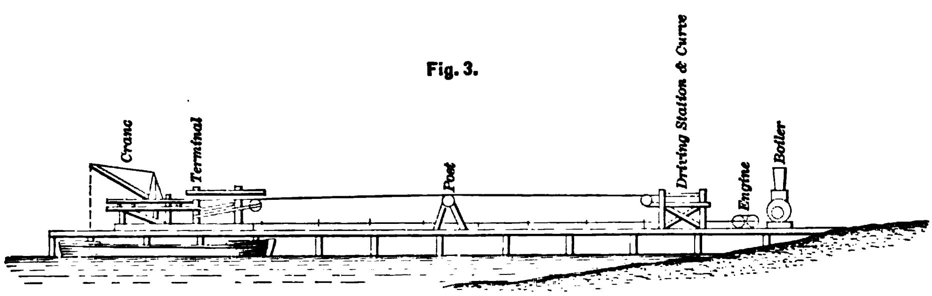


Fig. 3.



ELEVATION OF PIER.

below. Four buckets, each holding 2½ cwt., are lifted at a speed of 80 feet per minute, and deposited on to a deck alongside the terminal frame. The buckets are then pushed, singly, down an inclined plane, so arranged that they engage themselves on the hangers which, with their saddles, carry them on the line rope. In a similar way the empty buckets arriving, or the sacks for delivery, are detached and lowered into the barge. The terminal at the end of the longer section at the coal store is placed on a wooden platform, about 20 feet above the ground, and 120 feet long. At the end of this, farthest from the driving station, is fixed a horizontal drum 8 feet in diameter, carried on a strong wooden frame, round which the line rope passes, and which can be drawn back when required to take up any extension. The motion of the rope actuates the drum, which, by a pair of bevel wheels, turns a square shaft, extending along the center of the platform for its whole length. A crane of similar construction to that on the pier head is placed on the platform in front of the terminal, and can be moved from end to end, deriving motion from the line rope through the square shaft at any point. The jib of this crane is long enough to enable loads to be hoisted on either side of the platform, and to be put down just behind the traveling shunt frame, which stands about 15 feet in front of the crane, and which is arranged to slide up and down the full length of the platform in conjunction with it. Thus the sacks of coal, having been raised from the ground, are placed at the foot of the shunt stage, by which they are, having been hung on the hangers, pushed on to the moving rope, and transported to the pier. When coal is being brought to the store, it is tipped into an inclined shoot out of the buckets while they hang on the rail of the moving shunt. It will be seen from the arrangements described that the coal can be hoisted out of the barge at the pier head, transported to the terminal depot, and delivered into store, where it is duly put into sacks for re-delivery to the steamers; and when this is required the sacks of coal can be lifted up to the ropeway, a height of 20 feet, transported to the pier head, and deposited into the barges.

The rope is supported on the longer section by seven posts, which are fixed in the beach, and are of the usual construction, about 15 feet high; these posts carry bearing pulleys 2 feet in diameter, grooved to fit the wire rope, which is of crucible steel of a breaking strain of 16 tons. The rope is run at a speed of 3½ miles per hour. This ropeway is carried about 130,000 tons. Though it was only designed to lift and carry 15 tons per hour, it has on emergencies conveyed more than 25 tons in an hour.

The cost of maintenance of the rope has been about ½d. per ton, that of the machinery about ½d., chiefly owing to the breaking of the buckets by rough use when hoisting. Thus the cost of maintenance may be taken at 1d. per ton, not allowing for the special duty levied on the renewals on entering the island. The cost of labor employed in working this ropeway has been greater than usual, as natives are employed. It amounts to 1d. per ton, including tipping the coal into store, and attending the engine. The cost of working the crane and filling the buckets in the barge has been about ⅝d. per ton. The engine burns 7 cwt. of coal every twelve hours. The operations are generally superintended by an English foreman, who also looks after the other mechanical work on the establishment.

The cost of these works complete erected on the spot, but exclusive of freight and customs duty, was about £2,500, which also included the large staging at the depot, and the woodwork throughout. The whole of the materials were fitted together in England, marked and taken to pieces again. The erection on the site occupied about three months, and was carried out by Mr. W. P. Churchward, Assoc. M. Inst. C.E., from the designs and under the general supervision of the author.

DOUBLE FIXED ROPE SYSTEM.

The first example of the system of transport on fixed wire ropes is that of a series of self-acting inclines of a total length of 2,844 yards, forming a means of conveyance for the lead ore from the mines of the Sentein Mining Company, in the Pyrenees, near St. Girons, France. These mines, which are of great extent and unusual richness, are situated at a height of about 7,000 feet above the sea near the summit of a mule pass over the Pyrenees. Though they have been worked for many years, their elevated position has prevented them from becoming a financial success, the distance to the dressing floors being 2 miles in a direct line, and the fall about 3,000 feet. Immense expense was incurred by the former proprietors in constructing a cart road up to the mines, which, though extremely steep at many points, and very narrow, required to be about 10 miles long to connect the mines with the dressing floors.

On the property coming into the hands of the Santein Mining Company, the question of transport presented itself as vitally important to the profitable working of the mine. With the road it was possible to bring down by carts about 30 tons per day of lead ore, at a cost of about 8s. per ton, but this was only practicable in good weather, and in winter was impassable owing to the road snow. The Directors of the Sentein Company applied to the author to advise them on the question of applying wire rope transport for the greater part of the distance. He found it possible to recommend the application of a series of self-acting wire-rope inclines (common on a small scale in the district) by which the ore could be brought down to a point about ¾ mile from the works, from whence there was a good cart road. This suggestion was adopted, and wire ropeways were erected from the designs of the author, (Figs. 4, 5, 6 and 7).

The inclines are five in number; the lower terminals of one join the upper terminals of the next, as uitable spot for these junctions being found at the ends or sides of the spurs of the mountain near the line of the wire ropeway.

The lengths and inclinations of the sections are as follow:

No.	Yards long.	Yards fall.
1	271	83
2	675	230
3	410	90
4	978	430
5	510	130
Totals	2,844	913

No. 1 incline commences at the mouth of the mine, and forms a junction with No. 2 incline at the edge of a cliff about 300 feet high. No. 2 incline crosses a span of 675 yards, and joins No. 3 incline on an elevated point on the steep side of the mountain, a small platform being cut out of its side for that purpose. No. 3 incline, stretching across a deep ravine effects a junction with No. 4 incline at the extreme end of a spur of the mountain, a flat space being cut off its pointed top, the sides shelving at an angle of 60° with the horizon. No. 4 incline, spanning a valley 978 yards across, and about 1,500 feet deep, joins No. 5 incline on the side of the mountain. No. 5 incline stretches thence down into the bottom of the valley, terminating close to the cart-road to the works.

These inclines are identical in principle, differing only in length and inclination. They consist of two crucible-steel fixed ropes, of 75 tons breaking strain, anchored at the upper end, and stretched across the space between the terminals, the lower end being held by a pair of blocks fitted with Bullivant's flexible steel-wire rope, by which the fixed ropes are tightened. At each end they pass over a massive masonry saddle. The blocks by which they are tightened are fitted with a long flexible rope, to allow of their being slackened out enough to lie on the ground for the purpose of repairs; the strain put on them is about 12 tons. The carriers for the ore are made of steel plates, measure about 2 feet 9 inches long by 2 feet wide and 2 feet deep, and are hung on the fixed ropes by a curved hanger, fitting into a pair of plates carrying between them two deeply-grooved steel wheels 15 inches in diameter on the tread, which fits the fixed rope. These plates also carry a small wheel under the fixed rope, which is placed so as not to touch it, but to prevent the larger grooved wheels being jerked off.

The carriers empty by the bottoms falling on the turning of a handle fixed to their sides. They are intended to carry from 14 to 15 cwt. each. One of these is placed on each of the two parallel fixed ropes, and the two are connected by a light wire rope of 7 tons breaking strain, of such a length that when one carrier is at the upper end of one fixed rope the other is at the lower end of the second parallel rope. Thus, when one carrier is charged with 14 cwt. of ore while standing on the upper end of the fixed rope, it runs down this rope dragging up the empty carrier on the second fixed rope by means of the light hauling rope, the speed being governed by a powerful brake. This hauling rope apart, each wheel being fitted with a powerful brake.

The hauling rope passes over the first of these, next round a wheel 5 feet in

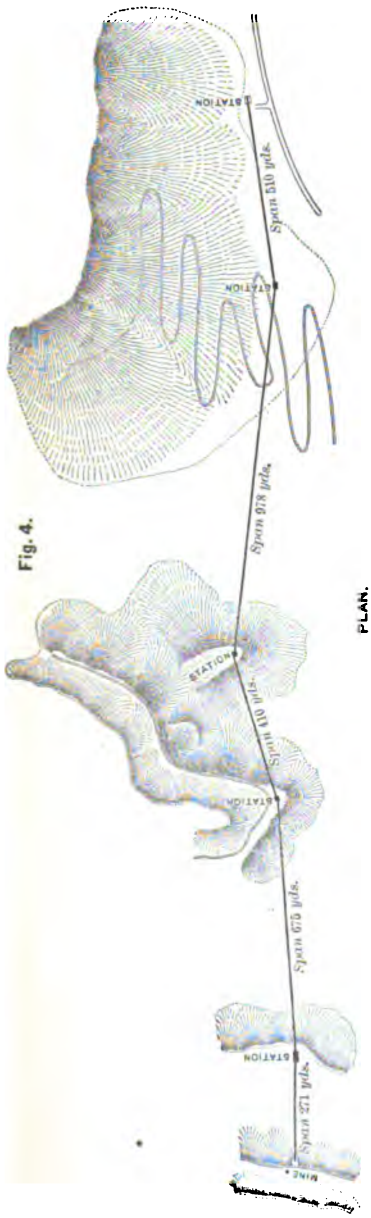


Fig. 4.

PLAN.

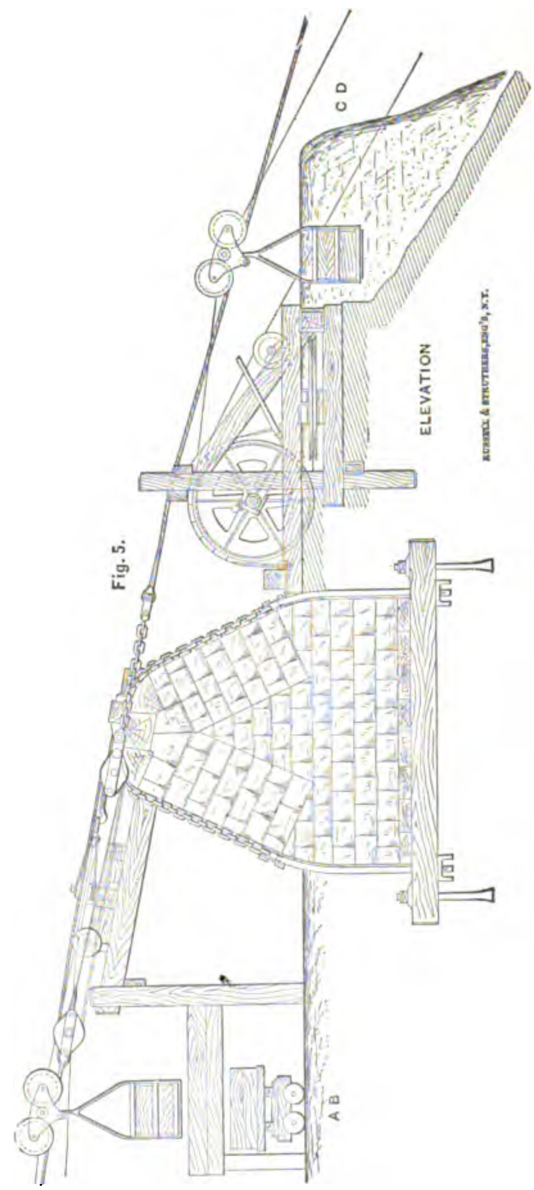


Fig. 5.

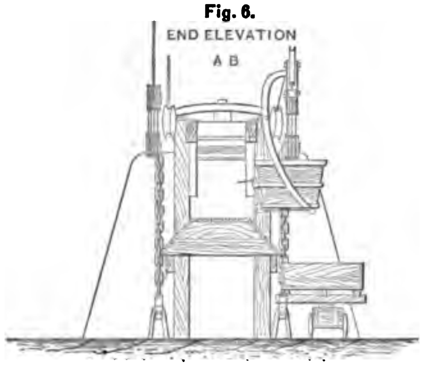
ELEVATION

passes round a brake gear at the end of the incline. It consists of two vertical wheels, 5 feet in diameter, having grooved wooden rims, placed 5 feet diameter, placed horizontally in front at the feet of the two vertical wheels, and then round the second vertical wheel; by this means the adhesion on the two vertical brake-wheels is equal to rather more than that derived from two half turns on these wheels. A second hauling rope of the same size connects the carriers by passing round a horizontal drum at the lower end of the incline, which is arranged to be drawn back by means of a screw, to regulate the tension on both the hauling ropes.

Owing to the great elevation at which most of the stations are situated, the erection of the works was difficult and expensive. The carriage of the ropes up the mountain was especially so; their total was about 30 tons, and it had to be divided into coils of 20 cwt. each, as it was impossible to take up by cart a heavier weight.

In conveying these 20-cwt. coils to the

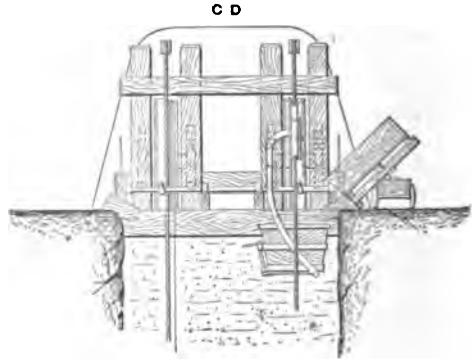
Fig. 6.



upper parts of the line five horses were required to each, and only one coil per day could be delivered. The transport of the machinery, carriers, &c., was equally difficult and expensive. In building the masonry saddles, owing to the frequent occurrence of frost at night, even during the earlier part of the autumn, it was impossible to place reliance on the mortar used, and the masonry saddles were therefore strengthened with massive timber trestles, fixed round the stonework, which assisted them in taking part of the vertical strain. On a future occasion, in such a situation, it would be advisable to use timber trestles only. By arranging the junctions of the adjoining sections the strain of one balanced to a considerable extent that of the other, and by the anchorage of the fixed ropes of each of these sections to the same foundation beam, which was placed under the saddles, and also strongly bolted down to the rock, the weight of the masonry materially increased their security.

As the inclines joined one another at a horizontal angle, and on very confined spaces of ground, it was found necessary to transfer the contents of the carriers from one section to the next, by small tip wagons running on a short and slightly-inclined rail between the point where the loaded carrier stopped to discharge to that where the empty carrier stood at the top of the adjoining section. These wagons ran easily, with the assistance of one man, who, when he had discharged the contents into the empty carrier, pushed it back into its place,

Fig. 7.
END ELEVATION
C D



ready to receive the contents of the next loaded one.

There was, of course, a similar arrangement on each side of each station; had it been possible to obtain better and more spacious sites for the stations, the usual arrangement would have been adopted—of placing the anchorages so that one carrier could tip its contents direct into the empty carrier on the adjoining section, and the lower ends of the fixed ropes could have been anchored by means of weights.

In working these inclines it was necessary to have three men at each station; one man at the brake gear, and the other two men attending to the emptying of the loaded carriers and the transmission of their contents to the empty carriers on the next section. The man at the brake had an uninterrupted view of the whole section. The speed at which the carriers are allowed to run is about 25 miles per hour; when the brakesmen had become accustomed to their duties, they could regulate their speed to a nicety, and bring the carriers to a standstill at the proper points with perfect smoothness and accuracy.

The quantity of ore which can be transported by these inclines depends, of course, on what can be got over the longest section; and while, owing to the exigencies of the route, it was necessary that the sections should vary greatly in length, it was attempted to equalize their carrying capabilities, by making the longer sections steeper than the shorter ones, thus enabling the carriers to be run on the former at a higher speed. To some extent this was successful. In putting up a series of inclines, such as those now described, it will be advisable to equalize, as far as possible, the carrying powers of each section.

The amount of ore which has been regularly brought down by this system has been from 70 to 80 tons per day, but if sufficient mineral were provided, 100 tons per day could be transported. A trial with the 675 yards section, before the men had become thoroughly acquainted with its working, proved that 12 tons per hour could be taken down. The cost of carriage is about 2s. 0d. per ton, exclusive of maintenance, which may be taken at 1s. 6d. per ton, or a total cost of 3s. 2d. The maintenance charge at these works will be exceptionally heavy, owing to their very exposed situation, and to the fact that for two months of the winter at least no work can be done, the plant, meanwhile, being exposed to the full deteriorating action of the weather.

By this ropeway the transport of mineral has been carried on without stoppage while the roads were buried in snow to a depth of several feet. The works have thus been supplied with ore for a much longer portion of the year than would have been possible by any other means of transport.

The cost of the whole work was about £5,000, of which only £2,200 were for the materials, the balance being for customs duty, freight, delivery from the nearest railway, 25 miles distant, cartage up the mountain and erection.

The work was erected in the nine months, from August to April, during six of which only could work be effeciently carried on, and in the remaining three months the weather and other causes prevented progress. Had the work been commenced earlier in the summer, it could probably have been completed in five months, and much of the erection would have been of far better quality.

SINGLE FIXED ROPE SYSTEM.

The second example of wire-rope transport on fixed ropes is a short length erected at the Nine Elms Works of the London Gas Light Company.

It was required to provide a means of transporting 24 tons per hour of gas coal across a dock in the above works to supply one of the retort houses. The point from which the coal was to be taken was about twelve feet above the ground, and it was required to deliver it into a hopper at the level of about 35 feet, the distance across the dock being 450 feet, and the incline consequently about 1 in 19 against the load. The company's engineer and manager, Mr. Robert Morton, M. Inst. C.E., requested the author to prepare a scheme for his consideration for doing this by wire-rope transport, and finally the arrangement shown by Fig. 8 was adopted.

It consists of a single rope of crucible steel wire, of 40 tons breaking strain, stretched across the dock. The upper end is fixed to a timber framing, attached to the retort house at about 45 feet above the ground, the attachment on which is tied back by another wire rope, exactly in the same line as that over the dock, the end of which is anchored to the opposite wall of the house near the ground. The lower end of the rope across the dock is held by a weight of 4 tons, acting on the double-purchase system, which thus exerts a strain of about 8 tons; by this means the strain on the rope is constant, whether the loaded truck is running on it or not. The truck is made of iron, and holds about 17 cwt. of coal; it is provided with a curved hanger, fitting into a running head which rests on a fixed rope. By a simple arrangement of a lever and catch, the bottom of the truck is let fall, and discharges its contents; the lever and catch are

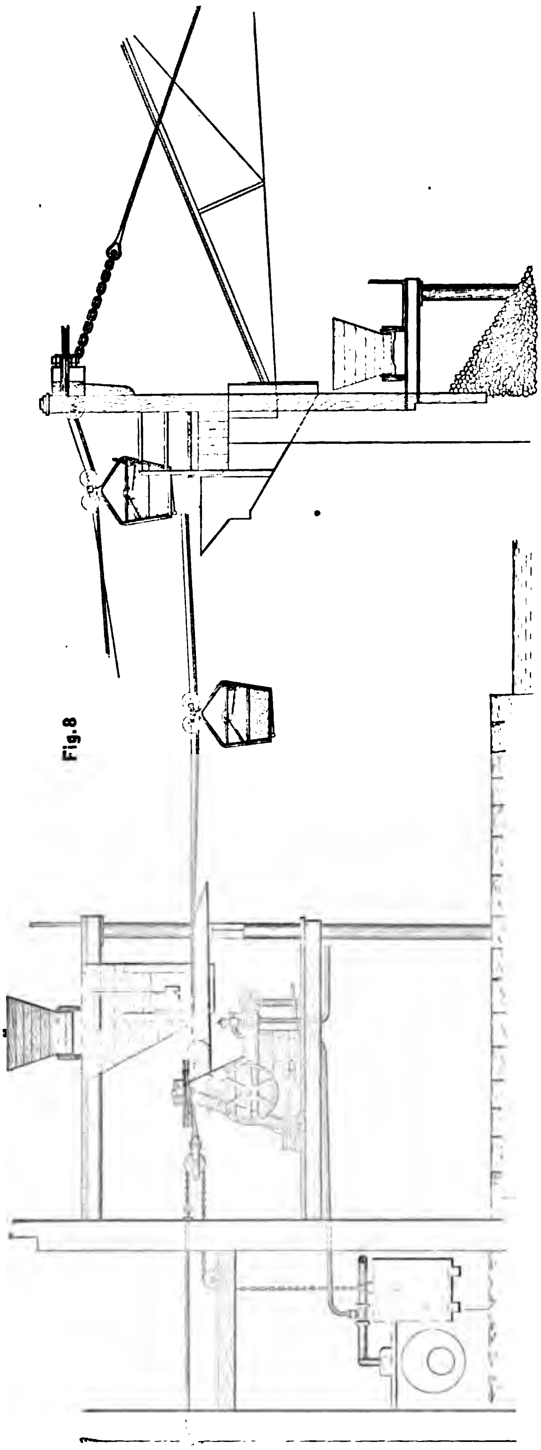


Fig. 8

placed on the side of the truck, and thus the attendant who stands at the delivery terminal can empty the truck and replace the bottom with very little effort and loss of time. At the lower or loading end the truck runs off the rope on to a rail, on which it stands under the door of a hopper containing the coal to be transported. This is let into the truck by a sliding door conveniently worked. The truck is made to stand on the rail under the hopper, in order that it shall be supported rigidly, and at the same height during this operation, which it could not do had it remained on the rope. When loaded, it is drawn across to the discharging end, hanging on the fixed rope by means of the running head, at a speed of five miles per hour, up a nominal incline of 1 in 19, but owing to the bend of the rope this is often as much as 1 in 10. The running head which has been referred to is formed of two strong iron plates, carrying between them, one near each end, two deeply-grooved cast-iron wheels, about 9 inches in diameter on the tread, and made to fit the fixed rope. The edges of their rims are turned true, so as to run on the rail under the loading hopper before referred to. These wheels are carried on steel pins fitted between the wrought-iron plates, through which, between the wheels, the curved hanger attached to the truck also passes.

This head with its suspended truck is moved along the fixed rope by a small crucible steel wire rope of about 4½ tons breaking strain, which passes round a horizontal drum fixed at the upper end of the line to the wooden frame which carries the attachment of the fixed rope, and is put in motion by a simple arrangement of driving gear at the lower end of the line. This driving gear consists of a horizontal wood-rimmed drum driven by bevel gearing, so arranged that it may be moved at 5 miles per hour in the forward, and at 10 miles per hour in the backward direction. The driving drum is fitted with two parallel grooves, and by means of a smaller drum placed at one side of it, the hauling rope may be made to pass twice round certains of its circumference, and thus increase its driving power. This contrivance also gives a means of taking up any small amount of stretch which may take place in the hauling rope.

The whole of the driving gear is carried on a substantial A-shaped wooden frame, and alongside it is placed a small engine of 6 nominal HP to provide the motive force. All the handles which control the motion of the driving gear, as well as that of a powerful brake on the fly-wheel of the engine, and that by which the loading hopper door is opened, are brought to a convenient spot where the driver can stand, who thus, without moving from his place, has control over all. In case the engine, which is of Tangye's "Soho" type, and of very short stroke, should stop on its center, a ratchet lever arrangement is placed on the end of the crank-shaft, so that the driver can move it off with ease. In working this ropeway it is found that 30 lbs. of steam will drive the engine at the required speed, thus giving 8 HP actual. The labor employed when working to the full capacity is as follows: One driver, one trimmer, and one man at the discharging end.

The method of proceeding is as follows: The truck having arrived under the loading hopper, the driver pulls up the door, and the bucket is filled, the trimmer with a shovel leveling the coal as it falls; the driver, shutting the hopper door, engages the forward motion of the driving gear, and the truck is drawn across to the discharging hopper, about 5 feet square, at the upper end of the line some 450 feet distant; the driver, putting on the brake, stops the motion, and on receiving a signal from the man at the upper end that he has emptied the truck and replaced the bottom, puts the backward gear in motion, and draws the truck back to the loading hopper at a speed of 10 miles per hour. In regular working the whole of the operations described occupy two minutes, and thus 30 runs are made in the hour. At a trial, however, it was found possible to load, transport, and empty, ten trucks in fifteen minutes, or about 30 tons per hour.

Since this line has been at work a small apparatus has been fixed to the driving gear, by which the driver can stop the truck exactly over the hopper. This was previously effected by placing a mark on the hauling rope, but owing to much of the work being done while it is dark, a more convenient arrangement was found advisable.

The labor is paid for at the rate of 0.88d. per ton. The renewal of ropes, wheels, and general maintenance, may be taken at 0.4d., of which the maintenance of the wire ropes is 0.26d. In all, excepting fuel, which in this case is the gas coke on the premises, the cost of loading, transporting for 150 yards up an incline of 1 in 19, and discharging, is 1.28d. per ton. The cost of the machinery ropes and steam engine for this work was £340. The erection aud the platforms were provided by the London Gas Light Company.

Such a ropeway is very suitable for transporting materials across a space where supports are inadmissible, such as ravines, rivers, from shore to a pier head, or pontoon in deep water, &c. The loads carried may be as heavy as 20 or even 30 cwt. net, as it becomes, under such circumstances chiefly a question of the strength of the rope. The author, some years ago, erected a similar means of transport over a valley 1,000 yards wide, without intermediate support, and in that case loads of 15 cwt. were moved.

The author trusts that by the examples, he has given of three descriptions of wire-rope transport, he has shown the applicability of the system under circumstances where the use of any other means would be either costly or impossible, and in such cases he believes this system may be advantageously used.

Fine Flooring.—The finest floors are said to be seen in Russia. For those of the highest grade tropical woods are exclusively employed. Fir and pine are never used, as in consequence of their sticky character they attract and retain dirt, and thereby soon become blackened. Pitch pine, too, is liable to shrink, even after being well seasoned. The mosaic wood floors in Russia are often of extraordinary beauty. One in the summer palace is of small squares of ebony, inlaid with mother-of-pearl. A considerable trade is done in Dantzic and Riga by exporting small blocks of oak for parquet floors. There is an active demand for these in France and Germany, but none in England.

THE THEORY AND PRACTICE OF VENTILATING COAL MINES.

By W. FAIRLEY, M.E., F.S.S.

I.

1. Motion in air is caused by pressure or difference of pressure—pressure is obtained by difference in density—and the movement is in the direction from the heavier to the lighter air. Pressure, or difference of pressure, as regards air circulating in mines, may be obtained either by the application of heat as by a furnace, or by exhausting the air mechanically from the workings by a fan; it is no matter which of these means is applied to procure difference of pressure, the result will be the same with the same difference of pressure however obtained.

2. If there are two shafts of equal depth, having a passage at the bottom connecting them, and the temperature and density of the air are the same in each shaft, then, as there is nothing to destroy the equilibrium of pressure, the air will remain stagnant.

3. If by some artificial means, as by a furnace, the temperature of one of the shafts is raised above that of the other, or there is an exudation of the lighter gases, then the air in that shaft will be less dense, and the air will move in that direction from the colder shaft—the heavier column descending and forcing up the lighter one with a velocity proportionate to the pressure caused by the difference of density.

4. If the tops of the two shafts were not on the same level, the atmospheric pressure would be the same at the same level above the surface, and the extra head of air above the shorter shaft, forming part of the outward atmosphere, would have the same effect as if it were contained in a shaft which rose to the same height. In this case, if the external temperature were lower than the temperature of the strata in which the shafts and the passage were made, the circulation of the air would be down the shorter shaft and up the longer one. On the other hand, if the exterior temperature be higher than that of the shafts and strata, the shorter shaft will be the upcast.

5. The *motive column* is a head of air of such a height that it will equal the difference of the weight between the air in the downcast and upcast shafts; and it is found by calculation from this rule:

$$M = D \times \frac{t_2 - t_1}{459 + t_1}$$

M = motive column D = depth of upcast in feet, t_1 and t_2 represent the temperatures of the downcast and upcast shafts respectively.

6. The motive column is really a measure of the pressure in force producing the ventilation, and if it is required to express it in pounds per square foot it may be calculated by multiplying the depth of the shaft in feet by the weight of one foot of air at the average temperature of the air in the shaft. Do this for each shaft and deduct the one from the other, the difference will be the pressure producing the ventilation. The following table gives the weight of a foot of air at various temperatures, and may be found useful to the student for this and other purposes.

Table showing the weight of a cubic foot of air in decimals of a pound avoirdupois, at different temperatures, calculated from the formula

$$W = \frac{1.32529 \times 30}{459 + t} = \frac{39.7587}{459 + t}$$

Temperature t.	Weight in decimals of a lb.	Temperature t.	Weight in decimals of a lb.
32	.0809749	120	.0686678
35	.0804831	125	.0680799
40	.0796767	130	.0675020
45	.0788863	135	.0669338
50	.0781113	140	.0663751
55	.0773515	145	.0658256
60	.0766063	150	.0652852
62	.0763122	155	.0647535
65	.0758753	160	.0642305
70	.0751582	165	.0637158
75	.0744544	170	.0632093
80	.0737638	175	.0627108
85	.0730858	180	.0622201
90	.0724202	185	.0617371
95	.0717666	190	.0612614
100	.0711246	195	.0607931
105	.0704941	200	.0603318
110	.0698746	205	.0598775
115	.0692660	212	.0592529

7. The force which operates in putting air in motion may likewise be expressed by saying it is equal to so much water-gauge, generally expressed in inches and decimals. With air and water at a temperature of 62°, the following rules will apply for converting the pressure into different terms:

Water gauge in inches × 5.196 = pounds per square foot.

Pounds per square foot divided by .0763122 = length of motive column in feet

8. The velocity of air without resistance is the same that a body would attain in falling the height of the motive column, so that if there is a difference of pressure equal to 34 ft. of air column, the theoretical velocity of the air would be about 47 ft. per second, because a falling body under the force of gravity, would attain a velocity of 8.025 times the square root of 34, or 47 nearly. It will thus be seen that were it not for the resistances encountered by air in passing along underground roads, a very small pressure would suffice to produce a great velocity. To show the theoretical velocity due to various pressures or motive columns, the table following has been constructed; from this we see that with 2 in. of water gauge, a very common pressure in colliery ventilation, a velocity of 93 ft. per second would be attained, but as air is retarded in its movement by rubbing against the sides of the channels, nothing like the theoretical velocity is reached in practice. The table shows likewise the pressure variously in pounds per square foot, inches of water gauge and feet of air column.

TABLE SHOWING THE AMOUNT OF MOTIVE COLUMN OF AIR AND INCHES OF WATER GAUGE NECESSARY TO PRODUCE THE THEORETICAL FINAL VELOCITY IN UP-CAST SHAFTS, WITH AIR AT DIFFERENT TEMPERATURES

Velocity in feet per second.	Motive column of air.	Water gauge in decimals of an inch at the following temperatures.								
$A = 8.025\sqrt{B}$	$B = \frac{A^2}{64.4}$	$C = \frac{\frac{1.32529 \times 30}{459 + t} \times B}{5.196}$								
		Degs. 90	Degs. 105	Degs. 120	Degs. 135	Degs. 150	Degs. 165	Degs. 180	Degs. 195	Degs. 210
5	.39	.005	.005	.005	.005	.005	.005	.005	.005	.004
10	1.55	.022	.021	.020	.020	.019	.019	.019	.018	.018
15	3.49	.049	.047	.046	.045	.044	.043	.042	.041	.040
20	6.21	.087	.084	.082	.080	.078	.076	.074	.073	.071
25	9.70	.135	.132	.128	.125	.122	.119	.116	.113	.111
30	13.94	.195	.190	.185	.180	.176	.171	.167	.164	.160
35	19.02	.265	.258	.251	.245	.239	.233	.228	.223	.218
40	24.84	.346	.337	.328	.320	.312	.305	.297	.291	.284

9. In practice from ten to twenty times as much pressure is required to give that momentum to the air which would suffice for the final velocity, on account of the friction air meets with in rubbing against the sides of the airways in passing round the underground workings.

10. If the whole friction of a mine be measured by 2.18 in. of water gauge, and the final velocity of the air in the upcast is 30 ft. per second—a common enough velocity in furnace shafts—the temperature of which is, say 135°, it will be found by calculation that 2 in. of this pressure is due to friction, the decimal portion only being required to produce the velocity, the water gauge due to final velocity being found thus:

$$\frac{\frac{30^2}{64.4} \times \frac{1.32529 \times 30}{459 + t}}{5.196}$$

The table given on page 186 has been prepared to show the height of water gauge required to generate the theoretical final velocities at various temperatures; this deducted from the total height of water gauge gives that which is to be referred to friction.

TABLE showing the comparative height of water gauge and air column at a temperature of 62 degs Fahr., with pressure in pounds per square foot and theoretical velocity of air due to this pressure.

NOTE.—Weight of cubic foot of air at 62 degs.=.0763122 lb., and of water =62.355 lb.

Water-gauge in inches.	Pressure in pounds per square foot.	Motive column of air in feet.	Velocity of air in feet per second due to motive column.
A= $\frac{B}{5.196}$	B= $\frac{A\times 62.355}{12}$	C= $\frac{B}{.0763122}$	D= $8.025\sqrt{C}$
.1	.5196	6.81	21
.2	1.0392	13.62	30
.3	1.5588	20.43	36
.4	2.0784	27.24	42
.5	2.598	34.04	47
.6	3.1176	40.85	51
.7	3.6372	47.66	55
.8	4.1568	54.47	59
.9	4.6764	61.28	63
1.0	5 196	68.09	66
2.0	10.392	136.18	94
3.0	15.588	204.27	115
4.0	20.784	272.36	132
5.0	25.980	340.45	148
6.0	31.176	408.55	162

EXAMPLE:—The quantity of air passing in an upcast having an area of 140 ft., is 210,000 cubic ft. per minute; the velocity is therefore 25 ft. per second, the temperature is 210°, then the water gauge due to velocity is by the table equal to .111 inch.

THE RESISTANCE OF AIR IN MOVING ALONG UNDERGROUND PASSAGES.

11. All experiments hitherto made with respect to the movement of fluids of every kind in pipes, passages or channels tend to prove that the resistance to the motion of the fluids is in proportion to the length of the passages traversed, to the perimeter of the section of the passages, to the square of the mean velocity of the fluids, and in inverse ratio to the section, or nearly so.

12. The following rules apply to the friction of air in moving along level passages of uniform size:—Let a = area of airways in square feet; h = horse power of ventilation; k= co-efficient of friction; l = length of air channel; o = perimeter of air channel; p = pressure in pounds per square foot; q = quantity of air circulating in cubic feet per minute; s = area in square feet of rubbing surface exposed to the air; u = units of work, foot pounds or power applied to circulate the air; v=velocity of the air in feet per minute; w=water gauge in inches; then

$$1.—a=\frac{ksv^2}{p}=\frac{pa}{p}=\frac{ksv^2q}{u}=\frac{ksv^3}{pv}=\frac{u}{pv}=\frac{q}{v}=\frac{q}{\sqrt[3]{\frac{u}{ks}}}$$

$$2.—h=\frac{u}{33000}=\frac{qp}{33000}\ \&c.$$

$$3.—k=\frac{pa}{sv^2}=\frac{u}{sv^3}=\frac{p}{\frac{sv^2}{a}}=\frac{w5\frac{1}{5}}{\frac{sv^2}{a}}.$$

$$4.—l=\frac{s}{o}.$$

$$5.—o=\frac{s}{l}.$$

$$6.—p=\frac{ksv^2}{a}=\frac{u}{q}=5\tfrac{1}{5}w=\left(\sqrt[3]{\frac{u}{ks}}\right)^2\frac{ks}{a}=\frac{pa}{a}=\frac{ksv^3}{q}=\frac{u}{av}.$$

$$7.—pa=ksv^2=\left(\sqrt[3]{\frac{u}{ks}}\right)^2ks=\frac{u}{v}.$$

$$8.—q=va=\frac{u}{p}=\frac{ksv^3}{p}=\sqrt{\frac{pa}{ks}}\,a=\sqrt[3]{\frac{u}{ks}}\,a.$$

$$9.—s=\frac{pa}{kv^2}=\frac{u}{kv^3}=\frac{qp}{kv^3}=\frac{vpa}{kv^3}=lo.$$

$$10.—u=qp=vpa=\frac{ksv^2q}{a}=ksv^3=q\,5\tfrac{1}{5}\,w=h\,33{,}000.$$

$$11.—v=\frac{u}{pa}=\frac{q}{a}=\sqrt[3]{\frac{u}{ks}}=\sqrt[3]{\frac{qp}{ks}}=\sqrt[2]{\frac{pa}{ks}}.$$

$$12.—v^2=\frac{pa}{ks}=\left(\sqrt[3]{\frac{u}{ks}}\right)^2.$$

$$13.—v^3=\frac{u}{ks}=\frac{qp}{ks}=\frac{vpa}{ks}.$$

$$14.—w=\frac{\frac{ksv^2}{a}}{5\frac{1}{5}}=\frac{p}{5\frac{1}{5}}.$$

13. These formulæ comprise the pressure referable to resistance, but not that necessary for producing velocity; so that they may be looked upon as more

correct for long passages than short ones; that is to say, the pressure required for the final velocity becomes a smaller fractional part of the whole drag as the pit workings extend. In a general way, for the sake of simplicity, the student need not take into account the pressure necessary for velocity; but if he desires to do so, instead of using p let him use $p-p_v$; p_v being the pressure required to generate the final velocity. In this case,

Instead of using $a=\frac{ksv^2}{p}$ substitute $\frac{ksv^2}{p-p_v}$.

Instead of $pa=ksv^2$, use $a(p-p_v)=ksv^2$.

Instead of $p=\frac{ksv^2}{a}$, use $p-p_v=\frac{ksv^2}{a}$, or

$$p=\frac{ksv^2}{a}+p_v.$$

Instead of $s=\frac{pa}{kv^2}$, use $\frac{(p-p_v)a}{kv^2}$.

Instead of $v=\sqrt{\frac{pa}{ks}}$ use $\sqrt[2]{\frac{(p-p_v)a}{ks}}$.

14. The co-efficient that will be used in working out the examples given in the following paragraphs will be that adopted by Mr. Atkinson, viz., .0217 lb. per square foot of area of section for every foot of rubbing surface and for a velocity in the air of 1,000 ft. per minute; or .0000000217 lb. for a velocity of one foot per minute, or $\frac{1}{46082950}$.

15. The area of a road, if square or rectangular, is found by multiplying the two sides together; thus a road 6 ft. high and 5 ft. wide = 30 ft. area. The perimeter of the same road would be $2\times6+2\times5=22$.

The rubbing surface is found by multiplying the perimeter by the length; thus a road to continue for 1,000 yards in length, and measuring 6 ft. $\times$ 5 ft., would have a rubbing surface (s) of $(1{,}000\times3\times22)=66{,}000$ square feet.

17. The quantity of air in cubic feet per minute is obtained by multiplying the velocity in feet per minute by the area; the horse power is obtained by multiplying the quantity by the pressure and dividing by 33,000.

18. The student must take care to clearly understand the difference between pressure (p) and power (u). Pressure is the force per square foot producing the ventilation, and power is the quantity passing multiplied by the pressure.

19. The co-efficient is found by dividing the pressure by the rubbing surface, multiplied by the velocity squared, divided by the area, or the value of $\frac{sv^2}{a}$ divided in the pressure (p).

20. The resistance is according to the length of the air channel for the same quantity of air, thus, if a mine were extended from 1,000 to 2,000 yards, the resistance would be doubled.

21. The resistance is according to the square of the velocity, and aircourses having the same pressure, area and perimeter, but different lengths, will pass quantities in accordance with the reciprocal of the square root of the length, or the square foot of the length divided into one. Suppose an aircourse 200 yards long pass 7,071 cubic feet, the quantities that will pass in aircourses of 400 and 600 yards long, with the same pressure, area, and perimeter, will be 5,000, and 4,082 respectively, because $\sqrt{\frac{1}{200}}=.07071$; $\sqrt{\frac{1}{400}}=.05$; $\sqrt{\frac{1}{600}}=.04082$ and the fact that lq^2 for each airway gives the same result proves the question.

22. The quantity of air circulating in a mine is according to the square root of the pressure; in furnace ventilation the pressure increases with the depth (provided the difference of temperature between the two shafts be maintained) and the ventilation with the square root of the depth of the upcast, so that by adding a stack of 30 ft. at the top of an upcast 150 fathoms deep the ventilation capabilities would be increased about $\frac{1}{60}$th.

23. If we obtain a certain quantity by a furnace and another by steam jet or other means, the combined effect will be according to the square root of the square of the one added to the square of the other; for example, if a mine circulates 25,000 cubic feet of air per minute by furnace alone, and 22,000 by steam jets alone, the quantity of air that will pass with the two acting together will be be $\sqrt{25000^2+22000^2}=33{,}301$.

24. The quantity of air passing is according to the cube root of the power

applied, and *vice versa*, the power necessary is according to the cube of the quantity; thus to treble the quantity of air in a mine the power necessary would be twenty-seven times as much, and if by an expenditure of 70,087 units of work 16,848 cubic feet be obtained, the quantity that would be got by employing 277,045 units would be 26,639, because:

$$\frac{16848 \times \sqrt[3]{277045}}{\sqrt[3]{70087}} = 26639$$

25. The quantity of air passing in airways of different areas, other things being equal is according to the square root of the area multiplied by the area. Thus, the pressure and rubbing surface being the same in each case, the quantity passing in an airway of 30 ft. area, when 20,000 ft. pass in one of 60 ft. area, will be 7,071, because

$$\frac{\sqrt{30} \times 20000}{\sqrt{60}} \times \frac{30}{60} = 7{,}071.$$

26. To make airways of different lengths of such area as to pass an equal quantity with the same pressure, apportion them according to the formula

$$a = \frac{q}{\sqrt[3]{\frac{u}{ks}}}$$

Thus, in a coal mine ventilated by five different splits or air currents:

The first	200 yards long and	9 ft. area,			
" second	400	"	"	?	"
" third	600	"	"	?	"
" fourth	800	"	"	?	"
" fifth	1,000	"	"	?	"

The areas of each of these, to pass the same quantities with the same pressure, will be found thus: reckoning the perimeter to be the same in each case, and taking the length in feet as the rubbing surface, and 10,000 cubic feet as the quantity passing in each road, then u will be found for the first airway by $\left(\frac{ksv^2}{a}\right) \times q$ = 17,860, and the value of $\sqrt[3]{\frac{u}{ks}}$ in each of the other roads is:

2nd, 881.883,
3rd, 770.400,
4th, 699.955,
5th, 649.780, then:

$$2.—\frac{10000}{881.883} = 11.339 \text{ area.}$$

$$3.—\frac{10000}{770.400} = 12.980 \quad ``$$

$$4.—\frac{10000}{699.955} = 14.286 \quad ``$$

$$5.—\frac{10000}{649.780} = 15.389 \quad ``$$

and the correctness of these areas is proved by finding the amount of pressure, p, for the assumed quantity, which ought to be the same in each case as below:

$$\left(p = \frac{ksv^2}{a}\right)$$

$$1.—\frac{.0000000217 \times 600 \times \left(\frac{10000}{9}\right)^2}{9} = 1.786 \text{ lb.}$$

$$2.—\frac{.0000000217 \times 1200 \times \left(\frac{10000}{11.339}\right)^2}{11.339} = 1.786 \text{ lb.}$$

$$3.—\frac{.0000000217 \times 1800 \times \left(\frac{10000}{12.98}\right)^2}{12.98} = 1.785 \text{ lb.}$$

$$4.—\frac{.0000000217 \times 3000 \times \left(\frac{10000}{15.389}\right)^2}{15.389} = 1.785 \text{ lb.}$$

which is sufficiently near. Or, as in this question the quantity (q), the power (u), k and q are all the same, we may cancel these factors in the equation $a = \frac{q}{\sqrt[3]{\frac{u}{ks}}}$ which will then be reduced to $\sqrt[3]{s}$, then the areas will be simply according to the cube root of the rubbing surface (s); and, as in this we consider the length as the rubbing surface, because the perimeters are all taken as equal, the result will be according to the cube root of the length, thus:

1. $\sqrt[3]{600}$ = 8.4343.
2. $\sqrt[3]{1200}$ = 10.6269.
3. $\sqrt[3]{1800}$ = 12.1644
4. $\sqrt[3]{2400}$ = 13.3884.
5. $\sqrt[3]{3000}$ = 14.4222.

We now say:

	area.
If 8.4343 : 9 : : 10.6269	=11.339 of 2nd airway.
" 8.4343 : 9 : : 12.1644	=12.980 of 3rd "
" 8.4343 : 9 : : 13.3884	=14.286 of 4th "
" 8.4343 : 9 : : 14.4222	=15.389 of 5th "

which areas are precisely the same as those obtained above.

27. If a continuous undivided road passing one current of air be of various dimensions, for the purposes of calculation it may be reduced to one typical road of uniform size throughout, the length (l') of which may be found by this rule:

$$l' = \frac{a'^3}{o'} \times \frac{s}{a^3}.$$

a'=area of typical road; o' perimeter of same, s and a = rubbing surface and area respectively of the original uneven road at each series of dimensions.

Example: The following are the measurements of an airway, and it is desired to calculate the length of a typical road which will measure 6 ft. square uniformly throughout, and that will offer equal resistance to it.

With a road 6 ft. square, $\frac{a'^3}{o'}$ will equal 1,944.

Length l. Feet.	Size.	Area. a Feet.	Perimeter. o. Feet.	Rubbing surface. $s=lo$. Feet.	Length of typical road $=l'= 1944 \times \frac{s}{a^3}$.
700	7×5	35	24	16,800	761.7
300	4×5	20	18	5,400	1312.2
400	8×3	24	22	8,800	1237.5
500	6×5	30	22	11,000	792.
200	4×4	16	16	3,200	1518.6
2,100	← Length of Original road.			Length of Typical road. →	5622.

Thus we see that the length of the new road would be 5,622, the old one being 2,100 ft.; and this may be proved in the following manner:—Put the quantity of air passing at 10,500 cubic feet per minute, then the pressure (p) for each part of the original road will be found by $\frac{ksv^2}{a}$=

lbs.

Each part of the original road.

1.— $\frac{.0000000217 \times 16800 \times 300^2}{35} = .9374$

2.— $\frac{.0000000217 \times 5400 \times 525^2}{20} = 1.6148$

3.— $\frac{.0000000217 \times 8800 \times 437.5^2}{24} = 1.5229$

4.— $\frac{.0000000217 \times 11000 \times 350^2}{30} = .9747$

5.— $\frac{.0000000217 \times 3200 \times 656.25^2}{16} = 1.8690$

Typical road:

$\frac{.0000000217 \times 134928 \times 291.6666^2}{36} = 6.9188$

The correctness of the result is shown by the pressure, p, required to pass the same quantity (which is taken at 10,500) through the typical road, being the same as is required in all the different parts of the original road put together, viz., 6.9188 lbs.

There are one or two useful practical lessons to be learnt from this illustration. In the first place it will be seen that the typical road of 6 ft. square and 5,622 ft. long will offer exactly the same amount of resistance—with the same quantity of air in motion—that is offered by the irregular road, the dimensions of which are expressed in the five series of figures. It is noteworthy that that part of the uneven road measuring 700 ft. long, and 7 ft. by 5 ft., only requires about half the pressure which is necessary to keep in circulation the same amount of air in that portion of the road measuring 200 ft. long, and 4 ft. by 4 ft.; this is of great importance practically and shows how the ventilating power of mines may be used up and wasted, as indeed, it too often is, by contracted airways.

28. The power required to circulate 10,500 ft. of air through an airway 1,000 yards long and 7 ft. by 5 ft., amounts to 42,182 units per minute, whereas the power required to circulate the same quantity through a road the same length, but only 4 ft. square, would amount to 294,368 units per minute. In other words, it would require an engine nearly seven times the power to pass the same quantity through the smaller airway as through the larger one.

29. The relative powers required to pass equal quantities of air through air-courses of the same length, but different areas and perimeters (o) will be found by this rule—$o\left(\frac{1}{a}\right)^3$,—and the table below shows the result of this worked out for five different sized airways:

Size of airways.	o.	a.	$o\left(\frac{1}{a}\right)^3=$	Relative powers making the road. 6×6=1.
6 × 6	24	36	.0005144	1.
5 × 5	20	25	.0012800	2.29
4 × 4	16	16	.0039062	7.59
3 × 3	12	9	.0164608	32.
2 × 2	8	4	.1250000	243.

Thus it will be seen that to pass the same quantity of air through a road 3 ft. square as through one 6 ft. square of the same length will require thirty-two times the power, &c.

30. In a channel or aircourse of uneven area and perimeter along which the air travels in one current, and which in calculation must be taken in a series of lengths of uniform size, the proportion of pressure or power that is taken up by each part of the road will be found by this rule $s\frac{\left(\frac{1}{a}\right)^2}{a}$, or $s\left(\frac{1}{a}\right)^3$

31. The pressure or power required to overcome the friction in passing equal quantities of air through circular airways or shafts is in inverse proportion to the fifth power of their diameters, or directly in proportion to $o\left(\frac{1}{a}\right)^3$.

The table below shows the relative pressure and powers required to overcome the friction in passing the same quantities of air through airways or shafts of the given diameters.

By the table it will be seen that 243 times the power will be required to pass the same quantity of air through a shaft 6 ft. diameter that is required to pass it through an 18 ft. pit, or through airways of these dimensions. The reader will do well to prove this, and he may do so by taking the usual co-efficient, and ascertaining the powers necessary for passing, say, 30,000 ft. of air through two airways, say, of 6 ft. and 18 ft. diameter respectively, and each, say, 500 yards long. This will be found by the rule $u=\frac{ksv^2q}{a}$, which for the 6 ft. diameter channel will be:

Diameter of shaft or airway.	Rule.	Relative powers for the same quantity.
18	—	1.
16	$\frac{18^5}{16^5}=$	1.80
14	$\frac{18^5}{14^5}=$	3.51
12	$\frac{18^5}{12^5}=$	7.59
10	$\frac{18^5}{10^5}=$	18.89
8	$\frac{18^5}{8^5}=$	57.66
6	$\frac{18^5}{6^5}=$	243.

$$\frac{.0000000217\times 28274.4\times 1061.04^2\times 30000}{28.274}=$$

732,839 units, and for the channel 18 ft. diameter:

$$\frac{.0000000217\times 84823.2\times 117.89^2\times 30000}{254.469}=$$

30,169 units, and $\frac{732839}{3016}=243$ nearly, which proves the question.

And the quantity of air that will pass in such airways with the same power is in inverse proportion to the cube root of the relative powers; or with the same pressure in inverse proportion to the square root of the relative powers.

The Chinese are beginning to like the electric telegraph after long objecting to it, and then tolerating it on a small scale in the private line between Mosung and Shanghai. The new line between Shanghai and Chinkiang was completed over two months ago, and has not yet been torn down.

In a paper recently read before the Académie des Sciences on the variations of the resistance of electric machines with their velocity, by M. Lacoine, the author shows reason for thinking these variations are explained by those of contact between the movable commutator and the springs in friction.

IMPROVEMENT OF THE DANUBE AT VIENNA.

A Lecture delivered before the Society of Austrian Engineers and Architects.

Translated by G. WEITZEL, Brevet Major-General, U.S.A.*

HIGHLY ESTEEMED ASSOCIATES: Being convinced that you take a lively interest in the great work which has been executed on the improvement of the Danube at Vienna, I will take the liberty to give you detailed information concerning the effect of such works as have so far been constructed in removing the danger of overflow at Vienna, based upon the observations which were made, and the facts which were established during this year's ice-flow and flood.

Since the projects for the improvement of the Danube which have been carried out are sufficiently well known to most of you, my esteemed associates, partly through my lecture delivered before this society on March 11, 1871, and January 2, 1875, and partly by the plans, opinions, and views of experts, which were published in our journal, I do not consider it necessary to-day to enter upon their renewed description.

I will also only recapitulate the chief periods of the formation and final moving of the ice gorges which were formed in the Danube during the past winter in so far as it may be necessary to sustain my arguments and conclusions, since Baron v. Engerth, court counsellor, has already communicated the details in his lecture of last Saturday.

Since the effect of every ice flow and flood can only be clearly appreciated in connection with the extent and position of the former and the height of the latter, I have at first arranged in the following tabular exhibit all of the extraordinary ice flows and floods which have occurred in the Danube at Vienna since 1826, and the highest gauge readings taken during their existence at the three chief stations, *i. e.*, at the great Tabor bridge, Nussdorf, and the Ferdinand's bridge across the Danube Canal.

The corresponding highest gauge readings at Linz and Stein are also incorporated, to enable one to judge whether the high stages at Vienna were caused by floods or by the damming up of the stream by the formation of ice gorges either in the bed of the river or canal.

From this table the following interesting data was obtained, viz:

1. During the period of fifty-one years, between 1826 and 1876, only three summer floods have occurred; but there have been nine heavy ice gorges, attended with floods, caused by the damming of the stream.

The latter are the most numerous, highest, and by far the most dangerous, because the height of water occasioned by them does not depend so much upon the discharge of the stream as it does upon the severity and length of the winter during which the ice gorge was formed, upon the manner and extent of the scourings and fillings caused by the ice in the beds of the river and the canal, upon the condition of the weather which causes the moving of the gorge, and, finally, upon the very weighty circumstance whether the moving of the gorge begins first at the up-stream or down-stream side.

It will be seen from the tabular exhibit that even during low stages in the main stream the water was raised to a considerable height by these scourings and heavy fillings in the beds of the stream and of the canal, and which occasionally have caused the water surface of the Danube Canal to be from 3′ 7⅛″ to 10′ 4½″ above that of the main stream. This was the cause of the destructive overflows which often occurred at the suburbs Leopoldstadt, Brigittenau, Rossau, and Weissgaerber, since several portions of the Vienna Danube Canal banks, as well as many of the streets and grounds in these suburbs, were only situated from 9′ 4″ to 11′ 5″ above the local zero of the gauge.

2. It is universally known that the winter of 1875–'76 was very severe, very long, and very prolific of snow; that on December 9, 1875, already it was neces-

TABULAR EXHIBIT.

Years.	Date of high water	Highest stages in the Upper Danube at— Linz.	Stein.	Date of ice flows and high water	Corresponding highest stages at— Tabor bridge.	Nussdorf.	Ferdnand bridge.	Notes on the ice-flows and high waters at Vienna.
		Ft. in.	Ft. in.		Ft. in.	Ft. in.	Ft. in.	
1829	June 10	10 1⅛	......	......	......	......	......	
	June 12	......	13 3¾	June 12	9 2	12 4⅛	12 3⅛	High water in summer.
1830	Mar. 1	14 9⅝	......	Mar. 1	19 8½	19 2⅛	22 10	The very high stages at these three gauges were caused by the removal of the ice-gorge to the Danube at Vienna and into the Vienna-Danube Canal, there damming the water. Through this the greatest and most destructive inundation of the 19th century, in which many lives were lost, was produced.
	Mar. 2	....	16 1	......	......	......	......	
1840	July 31	15 6¾	......	Aug. 2	9 3	12 1¼	12 6½	High water in summer.
1845	Apr. 1	16 6	......	......	......	......	......	
	Apr. 2	......	14 5	Apr. 3	9 2	12 3¼	12 11¾	The ice gorge formed at the Tabor bridge.
1847	Feb. 20	8 5⅜	7 5¼	Feb. 20	9 3	9 8¼	14 10¾	These rises were produced by masses of ice piling themselves upon each other in the Danube Canal as well as in the bed of the stream, and caused considerable overflows of the suburbs of Vienna.
1849	Jan. 16	8 1⅛	......	......	......	......	......	
	Jan. 17	......	6 11	Jan. 17	8 3½	10 9⅝	18 1⅞	
1850	Feb. 4	13 1¾	14 0	Feb. 4	14 5¼	12 8½	14 6¼	
1853	June 20	14 6½	......	......	......	......	......	
	June 22	......	13 0⅜	June 22	9 5	11 11	12 5½	High water in summer.
1861	Jan. 26	0 2	......	......	......	......	......	These high stages at Vienna were caused by the moving of the ice gorge into the Danube Canal and stream, in spite of the small discharge of the upper stream.
	Jan. 28	......	4 10	Jan. 28	10 4⅛	14 0	12 2¼	
1862	Feb. 3	16 2	......	......	......	......	......	After the complete and unhindered passing off of the ice gorge, in consequence of a sudden, warm and protracted rain, one of the highest stages was produced, which caused a great inundation.
	Feb. 4	......	19 2½	Feb. 5	12 2¼	16 5	15 9⅞	
1871	Feb. 11	4 11⅛	......	......	......	......	......	The ice gorge was formed at the Tabor bridge and in the canal, and caused a very destructive inundation of the suburbs of Vienna.
	Feb. 13	......	2 10¼	Feb. 13	9 0	17 4½	20 2¾	
					Emp'ror Francis Joseph's bridge.			
1876	Feb. 17	0 9⅝	......	Feb. 18	12 11½	14 6¼	14 11½	The gauge at the Emperor Francis Joseph's bridge read 14 feet, but was reduced to the zero of the gauge at the Tabor bridge, *i.e.*, to 12ft. 11½ins. The ice gorge moved partly through the Danube Canal, but mostly through the cut-off, and first stopped above the Northwest Railway bridge, and subsequently above the Stadtlauer bridge.
	Feb. 18	7 10½	4 7	Feb. 19	17 5⅛	At the Reichstrassen bridge.		
	Feb. 19	13 11	18 1¾	Feb. 19	19 4	At the Military Bath.		
	Feb. 20	14 9½	14 9½	Feb. 19	14 6¼	At the Stadtlauer bridge.		
		......	......	Feb. 20	12 11¾	11 8	10 9¾	

sary to close the lock at Nussdorf by means of its floating caisson in consequence of a heavy ice flow, and that, furthermore, in consequence of the position of the ice gorge in the Danube in Hungary, it had gradually so increased that it reached up to the Reichstrassen bridge; but then again had been shoved back and compressed by the force of the stream.

In consequence of the renewed heavy ice flows from the upper portions of the stream on January 10 and 29, 1876, which, with slight interruptions, continued until February 16, 1876, the gorge was again enlarged and in turn compressed, so that on the date last mentioned the Danube from below Pesth up to about 9½ miles above Tulla, that is, for a distance of about 235½ miles, was full of ice, which, in many places, reached the bottom. This gorge, which was formed in the Danube during ten weeks of a severe winter, may therefore be safely classed as one of the largest, strongest, and most dangerous of any one since the memorable year of 1830.

In consequence of the mild weather which came suddenly in the west of Europe on February 16, 1876, and which produced thaw, with rain, the water in the Danube rose considerably, and the gorge commenced moving above Tulla on the 17th and at Nussdorf on the morning of the 18th, at the time the stage was about 12 feet above zero, and was forced, with the addition of some large masses of ice from the improved stretch of the Danube at Vienna and the Vienna Danube canal, by the high water down to Fischamend, Petronell, and Hainburg. Here the masses of ice were piled high upon each other, since in the lower portion of the stream, in Hungary, the thaw had not yet had its effect and the gorge remained firm.

The circumstances attending such a forcing of an ice gorge by the thaw and high water from Tulla past Vienna and down to Hainburg, must certainly be considered as among the most favorable.

If we do not consider the high stages which occurred during the moving of the ice gorge on account of the partial back water caused thereby, and only those which ensued after the gorge had passed away, we find that the following high stages occurred:

	Ft.	In.
At Linz and Stein on Feb. 20, 1876....	14	9½
At Nussdorf on Feb. 20, 1876..........	11	8
At the Emperor Francis Joseph's bridge, at six o'clock in the evening of Feb. 20, 1876, and before the crevasse in the levee..........................	12	11½
At the Reichstrassen bridge on the evening of the same date................	12	9½

By comparing these with those of former years it will be seen that the stage in the Danube during and after this gorge belongs to the highest since the year 1830, and that therefore this event may be considered as one of the most remarkable ones produced by the elements during a period of 46 years. This is also conclusively proven by the numerous and destructive overflows of the cities situated above and below Vienna, particularly Passau, Linz, Krems, Hainburg, Grau, Waizen, and more particularly Pesth-Ofen. The consequences resulting from a sudden thaw after such a winter, in which much snow had fallen, were not only felt in the Danube, but on the Rhine, Elbe, and Seine, where many cities, and Paris even, suffered from higher and more destructive floods than have occurred since the last century.

3. Since, in former years, even with less extensive ice gorges and at much lower stages of water, the suburbs of Vienna were overflowed, and in the extraordinary gorge and simultaneous high water stages of this year Vienna was exempt from inundation (the flooding of a few low streets and grounds in Erdberg not being considered an inundation), it must be concluded after a thorough study of the present condition of the stream, the phases which were observed, and the data which were collected during this year's ice flow, that the city of Vienna was alone saved from a catastrophe similar to those which occurred here during the fatal years 1830, 1849, 1850, 1862, and 1871 by the improvements of the Danube which have been made.

In order to furnish more detailed proof of the statement just made, I will take the liberty of giving the following facts and observed data:

4. It is universally known that after a strong ice flow the gorge is at first formed mostly in the unimproved stretches of the stream below Pressburg, and then increases in extent up stream to above Vienna, and gradually fills up

the bed of the stream as it did in the past winter. In former years, however, the gorge was occasionally formed in the bend of the stream at the old Tabor and Northern Railway bridge, between their numerous wooden piles, and then extended up stream.

Furthermore, it is the universal experience that the ice gorges which are formed in an unimproved portion of the river, or one that is partly obstructed by bridge piles, can only be lifted and moved down stream by the increased force of much higher stages of water, as was the case at Vienna in 1830 and 1850. In the cut-off at Vienna, which is about 4½ miles long, has the form of a gentle curve, has a cross section about 311 yards wide, and is dredged to a uniform depth of about 10½ feet, no ice gorge was formed during the recent repeated ice flows. When in the beginning of January the ice had massed itself in the cut-off from Fischamend to the ferry, and then to the Reichstrassen bridge, the strong current repeatedly pushed it out and forced it down to Mannswörth. When finally, in consequence of the very heavy ice flow which occurred on January 29, 1876, the ice gorge extended from Pressburg to about 9½ miles above Tulla, the cut-off was, of course, filled up with masses of ice, but yet a strong current of water was still maintained through it, as was clearly apparent by the numerous open channels which were washed out.

When on February 16 and 17, in consequence of the sudden thaw and rain, the gorge commenced moving down from Tulla and from Nussdorf on the morning of February 18, only part of the ice masses which were rapidly piled upon each other remained in the cut-off between the Point and the Northwestern Railway bridge until four o'clock on the afternoon of the 18th. During this time a small part of the descending ice gorge passed under the floating caisson and through the canal, and the greater part passed on the left hand side of the high-water cross section. The latter portions flowed back into the cut-off just below the Northwestern Railway bridge, and moved out rapidly.

At four o'clock on the afternoon of the 18th the masses of ice which were piled up above the Northwestern Railway bridge finally moved where the water had been backed up to the height of about 14′ 5½″ on the gauge at Nussdorf, and then all the gorge that remained above passed through the cut-off at the 12′ 5½″ stage.

A part of the gorge remained just above the Stadtlau Railway bridge where the cut-off empties into the main stream. This occurred at the spot where the new left hand bank and the new levee on the left hand bank had not been carried across the old bed of the stream. The high water which carried the gorge, and which was confined between dams from Kahlenbergerdörfel down, ran off unimpeded at three places into the old bed of the stream and the left hand channel, and then left the gorge undisturbed.

This change in the location of the gorge caused back water in the cut-off, during the night of February 18 to 19, to the height of 19′ 4″ at the Military Bath; of 19′ 5½″ at the Reichstrassen bridge; of 14′ 6¼″ at the Stadtlau bridge, and 12′ 11½″ at the Emperor Francis Joseph's bridge.

This gorge passed off already, however, in the direction of Fischamend, during the night of February 19 to 20. A second gorge formed in the lower part of the Weidenhaufen cut-off, which is about 1¾ miles long, about 187 yards wide above the zero, but below that is dredged to a depth of 8′ 3⅝″, and to a width of about 125 yards, and which, for the present, has been left to the effect of high stages of water for its widening, deepening, and completion. This gorge forced the one which came down from the Stadtlau bridge to take the route in the old bed of the stream, which had not yet been completely dammed, at Albern and Kaiser Ebersdorf, in the direction of Fischamend. No injurious effect on the state of affairs at Vienna was caused thereby, but the incomplete dam at the head of the Weidenhaufen cut-off was washed away for a length of 247 feet.

The gorge in the Weidenhaufen cut-off moved on the morning of February 20, at the 13′ 5½″ stage. Based upon the foregoing presentation of facts which occurred during the formations, the positions, and the moving of this year's ice gorge, and the coincident high waters, the following conclusions can be drawn, viz:

a. If the cut-off at Vienna had not been in existence in 1876, and this year's heavy ice gorges, with accompanying high water, had been compelled to pass off by the crooked, irregular old bed of the stream, which is crossed by two wooden bridges and obstructed by numerous piles, it is very probable that a gorge would have been formed here, and the water backed up as high as in 1830. The result would have been an inundation, and possibly a crevasse in the weak levee alongside of the former bed of the "Emperor's" stream, and a consequent destructive overflow of the suburbs of Brigittenau and Leopoldstadt.

The damming of water in the old stream above the Stadtlau bridge to the height of 19′ 3⅛″ above zero, which actually occurred during this year's ice gorge, would have caused the overflow of the whole Prater and a portion of Leopoldstadt, since the old levee only reached as far up as the Emperor's Mills, and at many places the reference of its top was only16′ 7¼″. This was only prevented in the recent case by the banks of earth which were deposited along the new right bank of the stream, by the Commission for the Improvement of the Danube, from the point at Nussdorf to below the Stadtlau bridge. This bank of earth has an average width of from 245 to 410 yards, and its top is in reference 20′ 9″.

b. It will be seen from the tabular exhibit that in former years, whenever ice gorges and high waters occurred, the stage of the Danube at Nussdorf was in every case about 3′ 1¼″ higher than at the Tabor bridge; and, further, that in 1830, 1862, and 1871, the stage at Nussdorf reached the height of from 16′ 5″ to 19′ 2½″ above zero, whereby particularly the inundations of the suburbs of Vienna by the Danube Canal were caused.

During this year's extraordinary ice flow and high water, the highest stage at Nussdorf was only during a few hours 14′ 6¼″ above zero, and it is particularly due to this considerable diminution in the stage of the river at this point that the high water entered the Danube Canal with a largely reduced pressure.

This diminution in the height of the stage was only caused by the work executed by the Commission for the Improvement of the Danube, which consisted in removing the old works on the left bank of the river opposite Nussdorf, by which the normal cross section was increased in width from 174⅙ to 311$\frac{1}{10}$ yards, in moving back the Hubert levee by which the high-water cross-section was widened from 414$\frac{8}{10}$ to 829$\frac{6}{10}$ yards, and, finally, by excavating the whole overflowed banks an average depth of 5′ 2″, by which the high-water cross-section of discharge was increased about 10,753 square feet.

c. In former years the stage in the Vienna Danube Canal at the Ferdinand's bridge was at ordinary ice flows and high waters invariably from 2′ 1″ to 4′ 2′ higher than in the Danube at the Tabor bridge, and even attained the height of from 15′ 9⅞″ to 22′ 10″ above zero in the years 1830, 1849, 1862, and 1871.

During the recent ice flows and high waters the highest stage at the Ferdinand's bridge was during a few hours only, 14′ 11½″ above zero, therefore from 10⅜″ to 7′ 10½″ lower than in the four years just mentioned, and only 2′ higher than that of the Danube at the Emperor Francis Joseph's bridge. This considerable reduction in the high-water stage is due, firstly, to the reduction made in the heights of the stages at Nussdorf as above mentioned, and, secondly, to the influence of the floating caisson placed at the head of the lock at Nussdorf.

Court Counselor Baron von Engerth has already, on the 11th instant, delivered a detailed lecture on the functions of this floating caisson at the various stages of the formation of the ice gorges and their final moving, and I take the liberty here to mention, for the sake of preserving the connection only, that during the moving of the great ice gorge of February 18 portions of the masses of ice crowded themselves under the caisson, flowed rapidly away by the canal which had been kept thus free from ice; was stopped by the ice masses which had already formed in the bed of the stream at Albern, at the foot of the canal; filled up the bed and formed a gorge in the canal which reached up to the Emperor Francis Joseph's bridge and raised the water in the canal to a height of 15′ 5¾″ above zero. The back water of the canal broke through the newly constructed levee on the left bank, whose top was at reference 14′ above and below that bridge, and then, together with the masses of ice which floated down, poured into the lower part of the Prater.

The water then flowed off along the slope of the valley plain across the Freudenau to the lower end of the same, where it broke through the levee which was in course of construction, in several places, and then emptied itself into the old bed of the stream, which it was intended should be shut off at Albern.

Now, it is undeniably true that, after the completion of the mouth of the Vienna Danube Canal, wherever in future an ice gorge in the Danube is formed reaching from Pressburg to above Mannswörth, and thus closes the mouth of the canal, and then in consequence of a strong influx of ice masses under the floating caisson a piling up of ice masses in the canal and dangerous backing up of its waters might occur, it is necessary that, using the observations made of this year's ice flows and all the experience which has been gained, to make further thorough study and to discover and construct such other contrivances as will enable us, as far as may be necessary, to more completely shut off the flow of ice masses into the Danube Canal under the floating caisson at its head.

This floating caisson also did great service in another respect, in that, after it had been sunk deeper, it caused a smaller quantity of water to flow into the canal during the flood of February 19 and 20, and caused a difference in height of the water surface of the Danube at Nussdorf, and that of the Danube Canal at the Ferdinand's bridge, of from 2′ 0¼″ to 3′ 0⅜″, and this certainly contributed a great deal to preventing the inundation of the lower suburbs of Vienna.

d. The commission for the improvement of the Danube in the period from 1872–'75 also caused the Vienna Danube Canal to be dredged throughout, at its center line to a depth of from 7′ 3½″ to 9′ 4¼″, and on both banks to a depth of 5′ 2½″ below zero; furthermore removed all the bars in the bed of the canal, which were deposited by the creeks emptying into it, and which sometimes extended across the whole bed, and then with this dredged material, which amounted to about 713,640 cubic yards, raised all the lower portions of the banks between Nussdorf and the Emperor Francis Joseph's bridge to a height of at least 12′ 5¾″ above zero, and below the latter to the old mouth of the canal, at the so-called Prater corner, the banks were provided with levees with gentle slopes, whose heights vary from 12′ 5¾″ to 15′ 7″.

By this improvement of the Vienna Danube Canal the circumstances attending its discharges, especially during high water, were considerably bettered, since now the formation of ice masses in it and partial backing of its water cannot occur so easily as formerly. Besides this the very great benefit was secured that at a high water stage of 12′ 5¾″ even the low lands and streets which lie behind the levees cannot be overflowed, whereas this formerly occurred in many places at from 10′ 5″ to 11′ 5¼″ stages.

e. The commission for the improvement of the Danube, in 1873 and 1874, carried the Hurbert levee, on the left bank of the Danube, from Lang-Enzersdorf up stream; raised and strengthened it in a suitable manner, and finally joined it to the foot of the Bisam Hill, although this work was not included in the original approved project. This entirely prevents the discharge of the high waters of the Danube via Lang-Enzersdorf and Floridsdorf and the Marchfeld, a route which was again taken when the crevasse of 1862 in this levee occurred.

How important the reconstruction of this levee was is clearly to be seen from the events of 1874. Although it had been considerably strengthened by that time above its junction with the railroad dam leading to Stockerau, yet this part was in great danger of being broken through by the pressure of the high water, and a crevasse in it was only prevented by works of protection, which were carried on with the greatest energy by night and day.

After a thorough examination and appreciation of the facts and observations which have thus been enumerated, every experienced engineer will agree that the suburbs of Vienna were saved from a great and destructive inundation during this year's extraordinary ice flow and high water by the construction of the works of the Danube improvement alone.

Now, if in addition all of the works for the improvement of the Danube which are begun are once completed, the levees all firmly closed, the enlargement of the Weidenhaufen cut-off is completed to the normal cross section, the contrivance is added to the floating caisson at the head of the Danube Canal to thoroughly regulate the influx of ice masses, and, finally, when the improvement of the Danube is completed according to the manner suggested in the original project from Mannswörth to below Fischamend, it will be clear to every one that the danger of an inundation of the city of Vienna and of the Marchfeld by the occurrence of extraordinary action of the elements will be still further removed.

The extraordinary ice flow and coincident very high flood, as well as the loading test of the newly erected bridges, have furnished the truest and clearest proof that the project in accordance with which the improvement of the Danube has been strictly executed, and which was made after a correct understanding of the conditions of the stream and in accordance with well-tried elementary technical principles is correct, not only as a whole, but also in all of its details, and that the improvement of the stream has already this year fulfilled its first requirement; *i. e.* the removal of the danger of the inundation of Vienna, and that it will in the future undoubtedly fulfill it in a more brilliant manner.

Furthermore, the well founded hope exists that the other requirements demanded of this improvement of the Danube, *i. e.*, the improvement of the sanitary condition of the low suburbs of Vienna by the drainage of their surface water, the facilitating and enlivening of the commerce and trade of Vienna, and finally the creation of the necessary room along the new stream for the enlargement of the city, and particularly for the erection of large commercial establishments, will be fulfilled in the same satisfactory manner.

In conclusion, I take the liberty to communicate to my esteemed associates that at the large and important works which have been constructed on the stretch of the Danube between Nussdorf and the Weidenhaufen cut-off, *i. e.*, the five permanent bridges across the Danube cut-off; the ten portions of quay wall whose total length is 1,165¾ yards; the many landing staircases, whose total length is 493½ yards; the two large municipal bathing institutes and the large guard lock at Nussdorf (with the exception of a partial undermining of the concrete sole of the lock), not the least damage was caused by the ice gorge and high water, and that the protected banks on both sides were not washed in anywhere, and that they were only slightly damaged at a few places.

This pleasing fact again furnishes the proof that the tracé of the improvement conforms to the conditions of the stream, since it does not give occasion either to the ice gorges or the highly swollen stream to make direct attacks either against these works or the banks, and that these works have good foundations and are solidly built.

I consider that I ought to inform my esteemed associates in reference to the crevasse in the levee, across the old bed of the stream above the Tabor bridge, which occurred on the night of February 20 to 21, *i. e.*, after the ice gorge had moved off, that it did not result from a direct attack of the stream, but was caused by the circumstance that in consequence of repeated high water in the summer and fall of 1875 it was impossible to close the work on the left hand side at Roller before the beginning of winter. The work was, however, prosecuted with the greatest energy by day and night, and this newly piled up and unsettled earth of the levee was very much softened and then broken through by the hydrostatic pressure of the 14′ 6″ stage applied only on one side.

The immediate closing of the crevasse was ordered so as to hold the high water for the purpose of carrying off the ice gorge through the stretch, so dangerous to Vienna, at Nussdorf, and also to secure the two old wooden pile bridges (the Tabor and the Northern Railway) across the old bed of the stream against destruction by the ice.

The result of this precaution was entirely satisfactory, for the gorge which had formed above the Northwestern Railway bridge and had remained there until four o'clock in the afternoon of February 18, was lifted and carried off by the high water, which was firmly held between the levees on the two sides of the stream.

If this levee had not been completed, and the gorge had passed through the old bed of the stream, it is very probable that the two old wooden bridges above mentioned, which during the last few years have, in consequence of the intended closing of the old bed of the stream, been kept only in poor repair, would have been destroyed by the ice and high water. A greater loss would certainly have resulted from this than the expense occasioned by closing the crevasse in the levee.

5. The question has been raised by some whether the normal width for the cut-off adopted by the commission, and particularly the cross section of discharge, were sufficiently large to carry off, without damage, extraordinary high floods which occasionally occur, and I will therefore take the liberty here to discuss this very important question in detail. In the numerous projects which have been submitted for the improvement of the Danube since 1810, by various hydraulic engineers, only a single cross section of discharge for medium and high stages was adopted, and the following normal widths for the improved bed of the stream suggested, viz:

	Yards.
By Schemerl, director of the imperial board of public works in 1810, for the cut-off	414.56
For the total clear water-way of the proposed permanent bridge	601.46
By the former imperial and royal counsellor of public works in 1817, for the width of the united Danube	372.09
By Kudriaffski, director of hydraulic works in 1830, for the width of the united Danube, said to be based upon experiments and calculations	393.68
By Francesconi, imperial and royal counsellor of public works in 1847, for the clear water-way of the united Reichstrassen and Northern Railway bridge at Floridsdorf	452.74
By van Pasetti, imperial and royal ministerial counsellor in 1859, for the united Danube above Nussdorf	414.56
But from Lobau to Fischamand only	393.68

From this statement it is seen that the above-named hydraulic engineers who had been engaged on works on the Danube, at Vienna, during periods of from 20 to 40 years, made very different suggestions as to the normal width to be given to the stream.

The experts who were called together in 1867, and who declared themselves in favor of the improvement of the Danube by means of excavating a cut-off, recognized the necessity, in order that a good stage of water should be maintained in the improved river, that there should be a special narrow bed for the discharge of low and medium stages, and a second enlarged so-called high water cross section for the discharge of high stages. Upon this, these experts, having studied the older maps of the Danube and the state technicists, having communicated to them the circumstances attending the discharge of the Danube, proposed 345.57 yards for the normal width of the cut-off for low and medium stages, and 829.12 yards for that of the high water cross section. This proposition was adopted by the commission for the improvement of the Danube which existed at that time.

Based upon the thorough studies of the circumstances attending the discharge of the Danube which were concontinued by me, and the fact which was thereby established that the discharge of the stream at low and medium stages had decreased during several decades in a remarkable manner, I submitted a proposition on May 24, 1872, to the commission. that the normal width of the cut-off between the edges of its two banks should be confined to 302.92 yards, but that the width of the high water cross section be retained at 829.12 yards, and at the same time furnished them with the calculations based upon hydraulic formulas on the motion of water in river beds, showing that this modified cross section would be quite adequate for the unimpeded discharge of the medium and high stages.

The commission called together seven distinguished hydraulic engineers, among them two foreigners, to decide this highly important question, and then, after an almost unanimous opinion from them, restricted the normal width of the cut off for low and medium stages to 310.57 yards and retained the width of the high water cross section at 829,12 yards.

In accordance with these widths the cut-off, the high water cross section, and the levees on both banks were constructed so that the cross section of the stream intended for low and medium stages is smaller, but that for high water is very much larger than those proposed by the above named five hydraulic engineers.

I believe that I should now show that the cross section of this improved portion of the stream, which has been carried out, is fully adequate to the unimpeded discharge of even the highest floods.

According to the measurements made by Kudriaffski, director of hydraulic works, the discharge of the Danube at Vienna should be per second:

	Cubic feet.
At the zero stage	70,269
At the 4′ 10″ stage	146,187
Where the banks are full, that is, at 12′ 5⅛″ stage	256,638

I could not ascertain from public documents the time in, the place where, or the manner in which these measurements wers made.

The former imperial and royal ministry of commerce and public works charged Mr. Nicolaus, who was at that time inspector of hydraulic works, with measuring the discharge of the Danube in 1850 and 1851, at Nussdorf and about 2¼ miles further up at the Kuchelau, in regular cross sections four times daily, and with the greatest possible accuracy. He found that the discharge per second was as follows, viz:

	Cubic feet.
a. At the 1″ stage above zero at the cross section at Nussdorf	55,861
b. At the 2″ stage above zero at the cross section at the Kuchelau	56,426
c. At the 2′ 8″ stage above zero at Nussdorf	74,298
d. At the 2′ 9″ stage above zero at the Kuchelau	81,921

These results may be considered perfectly reliable, because the manner of measurement was entirely rational; furthermore, because Inspector Nicolaus is known to all the older officers in charge of public works to have been an experienced hydraulic engineer and as a man who executed all works intrusted to him with conscientious accuracy; and, finally, because the discharges measured at Nussdorf and the Kuchelau so nearly agree.

It appears from these measurements that the discharge of the united Danube above Nussdorf at the zero stage is about 55,000 cubic feet per second, and that, therefore, this discharge given by Kudriaffski, *i. e.*, 70,000 cubic feet per second, is clearly about 20 per cent. too high. That the discharge given by Kudriaffski, when the banks are full, at the 12′ 5⅛″ stage, *i. e.*, 256,638 cubic feet per second, was not measured, but either estimated or approximately calculated, is apparent from the fact that since 1826 there has not been so high a stage at Vienna; furthermore, because there are no places in the vicinity of Vienna where there is a complete cross section with banks 12′ 5⅛″ high; and, finally, because during such an extraordinary high stage the velocity of the stream is so great that it would be almost impossible to measure a cross section and take the velocity at many points and at different depths thereof.

The Hungarian hydraulic engineers have, in former as well as in latter years, repeatedly measured the discharge of the Danube at different stages, and with the greatest possible accuracy between Pesth and Ofen, where the concentrated river flows between high banks, and, on account of its smaller slope, has a smaller velocity.

The distinguished engineer Reitter, ministerial councillor, had the kindness to send to the Society of Austrian Engineers and Architects the result of these measurements, as well as the gauge-readings from 1857 to 1873, from which I will only select the following as being very interesting to us.

By comparing the gauge-readings at Vienna and Pesth during the period from 1855 to 1867 it will be seen that when the river has reached the zero of the guage at the Tabor bridge the corresponding stage observed two days later gives a reading of from 5′ 5⅓″ to 6′ 4¾″ above zero at the gauge at Pesth, and that the mean of the gauge-readings at Pesth during a period of nine years, where the river had arrived at zero at Vienna was 5′ 9″.

Since the discharge of the Danube at Pesth at this stage was determined by measurement to be 59,604 cubic feet, and since the small tributaries of the Danube between Vienna and Pesth discharge into it at a low stage hardly more than 4,604 cubic feet per second, the measurements of discharge made at Pesth prove the measurements made above Nussdorf by Nicolaus, inspector of hydraulic works, to be more nearly correct.

According to the tabular exhibit given at the beginning of this paper, it appears that the highest stage of water which has occurred since 1826 at Vienna without an ice gorge was on February 5, 1862, when the gauge reading was 12′ 2¼″

above zero; this passed off between Pesth and Ofen on February 7 and 8 with a constant gauge reading at that point of 15′ 8¾″. Now, since according to the report of the ministerial councillor, Reitter, which was furnished us, the measurements made between Pesth and Ofen show that at the 15′ 8¾″ stage the discharge of the Danube is there 184,462 cubic feet per second, and when it is considered that between Vienna and Pesth the tributaries March, Leitha, Raab, Waag, and Grau, must have discharged in the high stage during the period from February 5 to 8, 1862, more than 5,932 cubic feet per second, it follows that during the high stage of February 5, 1862, the discharge of the Danube at Vienna could not have been greater than about 178,530 cubic feet per second. Comparing this with the statement of Kudriaffski, director of the hydraulic works, who, it is true, assumed a stage $3\frac{1}{12}$″ higher, there will be found a difference of 79,108 cubic feet.

In order to prove that the cross section, according to which the cut-off at Vienna was actually executed, is fully adequate to discharge the quantities of water which, as has been shown, pass through, my associates will please make the following hydrotechnical calculation with me.

The latest and most reliable hydraulic equation to determine the velocity of water in rivers and streams is that of Gauquillet and Kutter, which has for Austrian measures the following form, viz:

$$v = \left\{ \frac{41 + \frac{1.779}{n} + \frac{0.00276}{J}}{1 + \left(41 + \frac{0.00276}{J}\right)\frac{n}{\sqrt{R}}} \right\} \sqrt{RJ}$$

In this equation v denotes the mean velocity of the stream throughout the whole cross section; J the slope of the stream; R the mean depth which is obtained by the dividing of the arm of the cross section F by the wetted perimeter U, and finally, n, a coefficient obtained by experience, and which depends upon the friction of the material which forms the wetted perimeter.

The discharge per second, M, is obtained by multiplying the area of the cross section F by the velocity of the stream v, *i. e.*, $M = F\,v$.

Since the average slope of the water in the cut-off at the zero stage is $J = 0.0004427$, and the coefficient of friction, according to the experiments made by Strauss, at Speyer on the Rhine, and by Destrem, on the Neva, can be taken at $n = 0.026$, we will obtain the discharge as follows:

I.—*At the zero stage.*

It will be found from figure I that the area of the cross section $F=8320$ square feet

$$U=856.72' \quad R=\frac{F}{U}=9.7114'$$

hence $v=5{,}467'$

and $M=5077$ cubic feet.

Now, since about 3,354 cubic feet per second of the discharge above Nussdorf are carried off through the Vienna Danube Canal, and about 1,677 cubic feet per second are drawn off at Greifenstein for irrigating the Marchfeld, it will be seen that the cross section of the cut-off which has been adopted is quite adequate for the discharge of the low and medium stages.

II.—*At the* 12′ 5⅓″ *stage.*

Although during the high stage especially when it is rising, the slope of the stream is generally greater than at the zero stage, yet I will assume this slope as unchanged, and call

$$J=0.0004427.$$

Furthermore, at high stages, the discharge of the stream through its normal bed must be calculated separately from that over its overflowed banks.

For the normal bed we will find—

$$F_1=18940 \text{ square feet} \quad U_1=909'$$

$$R_1=\frac{F_1}{V_1}=20.836'$$

therefore $v_1=8.754'$

$$M_1=F_1\,v_1=184992 \text{ cubic feet.}$$

For the portion of the cross section above the overflowed banks we find—

$$F_2=69.96 \text{ square feet} \quad U_2=1480'$$

$$R_2=\frac{F_2}{U_2}=4{,}727'$$

therefore $v_2=3.382'$

and $M_2=26412$ cubic feet.

The capacity of the cross-section for discharge at the 12′ 5⅛″ stage, where the water just reaches the top of the right-hand bank, is therefore—

$M_3 = M_1 + M_2 = 211{,}404$ cubic feet.

Consequently about 32,900 cubic feet more per second than the discharge of the Danube at Vienna during the highest flood on February 5, 1862.

Now, if it will be further taken into consideration that of the high water which passes Nussdorf about 15,600 cubic feet per second are discharged by the Vienna Danube Canal, and it is still further considered that, as shown by my lecture of March 11, 1871, after the improvement of the Danube to Fischamend, and the inevitable equalization of the slope which will ensue, the zero will be lowered in the cut-off at least from 1½″ to 2″, which is equivalent to raising its banks to that height, I believe that every experienced hydraulic engineer will agree with me that the normal widths and the cross section of discharge which have been adopted are adequate for the unimpeded discharge of the highest floods, and that these will never rise over the 12′ 5⅛″ high-water bank.

As a protection against the backing up of the water which may now and then be caused by the ice gorges, but which will not occur so often on the Danube where it is improved, and will not rise so high, the levees on each bank have been built to a height of 20′ 9″ above zero.

Now we will see what observations were made during the high water which came immediately after the gorge moved on the afternoon of February 20.

Although the gauge readings of Linz and Stein were not as high on February 19 and 20, 1876, as those on February 3 and 4, 1862, yet, I believe that in consequence of the sudden melting of the large masses of snow between Linz and Vienna, which was caused by a warm and steady rain, that the high-water discharge at Vienna was as great on February 20, 1876, as it was during the highest stage of 1862. During this year's high water the following gauge readings were taken at 6 p. m. on February 20; that is, before the crevasse in the levee at the Tabor bridge occurred, viz:

	Ft.	in.
Above Nussdorf, where the whole new cross section of discharge was completed	11	8
At the Emperor Francis Joseph's bridge, above the new zero	14	
And therefore above the old zero at the Tabor bridge	12	11¾
And finally at the Reichstrassen bridge.	12	9¼

The reason that the gauge readings were higher at the last two mentioned bridges than at Nussdorf is that in the cross section of discharge at the former bridges the old spoil banks and the old Prague Reichstrassen dam had not been completely removed, and the six houses which stood there had not been torn down, and, furthermore, because the scaffolding, laborers' barracks, restaurants, bath houses, and an elevated railway for the transportation of the material for completing the Reichstrassen bridge still remained, and, finally, because some masses of ice had been shoved on to the banks just below the Reichstrassen bridge, and still remained.

On this account the discharge of the stream was considerably impeded, and its surface raised.

It will be clear to every expert that if the high-water cross-section of discharge along the whole cut-off had been as completely open and unobstructed as at Nussdorf, the high-water mark of this year in the cut-off would not have gone beyond 11′ 8″ above zero, from which it will be seen again that after the works on the improvement of the Danube at Vienna are once completed that the cross section of the discharge will be adequate for the highest floods that will occur.

The high water of February 20 lasted, with slight variations, until February 24, and the high-water marks at the different places were as follows, viz:

At Linz, from 13′ 8″ to 14′ 9½″.

At Stein, from 14′ 6″ to 15′ 6¾″.

At Greifenstein, from 11′ 11″ to 12′ 5¼″.

At the Kuchelau, from 14′ to 14′ 8½.″

At Nussdorf, from 11′ 5″ to 11′ 10″.

*At the Emperor Francis Joseph's bridge, from 9′ 7″ to 10′ 1¼″.

*At the Ferdinand's bridge, in the Danube Canal, from 10′ 3½″ to 11′ 1¾″.

From this it will be seen that the high water of this year lasted a long while.

I now hope that my esteemed associates, afer a thorough examination and consideration of the facts and data which

*At these two bridges the water was considerably lowered by the crevasse.

have been given by me concerning this year's inflow and high water and the hydraulic calculations which I have added, will agree with me in the conclusion that the city of Vienna was alone saved from disasters, similar to those which occurred so often in former years, by the works on the Danube improvement, and that after these are thoroughly completed the protection of the city of Vienna against the danger from overflow will still be far more complete.

Finally, I beg you, my esteemed associates, to allow me to refer to the unfavorable opinions which have been published in many newspapers, partly upon the project for the improvement of the Danube and partly upon the effect of the works which have thus far been completed.

Since I and my professional colleagues have not time to reply to all attacks in the separate journals, we will leave them unanswered, in the hope that a true appreciation of the favorable effect of the works which have thus far been executed will in the end compel recognition.

The results of those one-sided statements and unwarranted attacks on the Danube improvement, have, however, not remained unnoticed.

At first I received letters from my friends in the provinces, in which they try to console me for the total failure of the works, as represented in Vienna journals.

The *Times*, in its issue of February 25, 1876, contains a communication from its correspondent in Vienna concerning the executed portion of the Danube improvement, in which he says that this great work has not fulfilled the hopes of its projectors, and that, on the contrary, it must be considered a total failure, since during this year's ice-flow the inundation of the suburbs Rossau, Leopoldstadt, Erdberg, and the country in the direction of Simmering was just as great as in former years, and that even the new central cemetery was so flooded that the corpses floated out of their graves, and that it was necessary to suspend interments in it during a long period.

Esteemed associates: You see how by such untrustworthy reporters, whose judgment of the project for the Danube improvement is based upon incorrect information and want of knowledge, this successful undertaking, which was much praised during its erection not only by the international jury, but also by more than twenty distinguished foreign engineers, and upon which Austria and Vienna may look with pride and satisfaction, is placed in bad credit and lowered in the estimation of foreigners.

I desire to refer particularly to an anonymous pretended expert who has already, in four articles published in the New Free Press, and entitled "The inundation and its causes," and based upon incorrect data and imaginary hypotheses, designated the whole project for the Danube improvement as a failure, and states even that the works which have been executed were the cause of the pretended inundation of Vienna.

Such a one-sided abuse, for I can no longer call it criticism, of the whole undertaking is so much the more to be regretted since the New Free Press is one of the most respectable papers in Austria, and is the most widely distributed in foreign countries.

In the short time allowed me I cannot recount and correct the many erroneous statements, defects, and charges made by the anonymous expert against the Danube improvement, but I hope you will permit me to point out some of the most glaring defects, since I am convinced that this alone will easily enable you to form an opinion of the knowledge of hydraulics possessed by this expert, and of his one-sided censure of the project for the Danube improvement.

1. The anonymous expert believes that the Danube cut-off was simply traced in plan as a curve to please the eye, without regard to the natural conditions which govern the bends of streams, and that thereby the resistence of the forces of nature was developed. He cannot justify the moving of the river nearer the city, and intimates that it would have been more advantageous to have allowed the Danube to remain in its old bed at Floridsdorf.

Gentlemen: In my lecture of March 11, 1871, I communicated to you that after a dispute lasting through a period of fifty years, and in which twenty-eight of the most distinguished native and foreign hydraulic engineers took part, it was finally concluded in 1867, to the great joy of Vienna and Lower Austria, to improve the Danube by a cut-off. This conclusion was approved on all sides.

Now, after this cut-off has been made at great expense, repays itself bountifully, and has proved itself during the recent events caused by the elements, as very advantageous, this anonymous expert, plainly without any knowledge of antecedent proceedings and works of experts, utters this oracle, that there was no need of a cut-off, and that it would have been better, therefore, to have left the stream in its bend at Floridsdorf.

You will find it, esteemed gentlemen, quite natural that I do not now enter upon a discussion of such an oracle.

2. The anonymous expert states that the old bed of the Danube had a depth of 20′ 9″ below zero, and since the cut-off was dredged only to 10′ 4½″ below zero, the water must raise itself up in order to get into the cut-off, and then besides that in the shallow cut-off the formation of ice and ice gorges was more extensive, and that consequently the water of the stream was forced through the Danube Canal. Based upon these premises he makes the following assertion, viz: "The new cut-off forms throughout its whole length an artificially constructed dam of earth in the old channel." He further says that the cut-off in its present condition is not only of no assistance in removing the danger of overflow, but is even an absolute obstacle against the free flow of the ice and water.

I must at first remark by way of correction, that the premises of this expert are entirely incorrect, since the depth of water in the Danube in its old bed was only 20′ 9″ in the concavity of its bends, but in the stretches between these, and even in the channel, the depths did not exceed from 6′ 2¾″ to 7′ 3″, and the arithmetical mean of the depths taken on seven different cross sections was found not to exceed from 9′ 4″ to 10′ 4½″ below zero; furthermore, I have shown in this lecture that the ice-gorge never came to a stand in the cut-off, but that in every case it formed from Pressburg upward, and naturally, therefore, the cut-off was filled with masses of ice.

It is also well known to you, my esteemed associates, that it is customary in making a cut-off to excavate a trench of from 62½′ to 124⅝″ in width and about 3⅛′ in depth, and to leave its further deepening and widening to the power of high waters.

The commission, on the contrary, in order not to expose the city of Vienna to the danger of an overflow during the progress of the work, at great expense, and by the use of a suitable plant, caused the cut-off to be dredged throughout its whole length of about 4⅛ miles, to its whole width of 311⅛ yards, and to the depth in its upper half of from 10′ 4½″ to 11′ 5″, and in its lower half of from 8′ 3½″ to 10′ 4½″ below zero.

I must, before proceeding further, admit that I do not know of any case in which such a colossal cut-off was dredged throughout its whole length, breadth, and depth, and yet this complete construction of the cut-off seems still too small to this anonymous expert, and he censures those in charge of the work with sharp, insulting words for having thereby exposed Vienna to the danger of an inundation.

My esteemed associates will agree with me that these assertions of the pretended expert, and particularly his utterance, printed with large type, that the new cut-off throughout its whole length is an artificially constructed bank of earth in the old bed of the stream, are technically and logically very incorrect, and are only calculated to lower the work in the eyes of laymen, and to awaken in the latter a totally ungrounded fear of danger from overflow.

3. This anonymous expert has also uttered the following oracle, *i. e.*: If the floating caisson had realized the expectations of its inventor, the inundation would have reached an unprecedented height, the water and ice, whose natural flow was obstructed, would have taken the next best route through Nussdorf, and the Danube might possibly have again taken possession of its old bed along the Salzgries, which it left hundreds of years ago.

If that portion of the masses of ice which came down from Klosterneuburg, which passed into the canal under the floating caisson, had been shut out by the latter it would also have passed off over the overflowed banks, which are 518⅓ yards wide, and its flow would only have been delayed several hours.

Furthermore, if after the ice gorge which formed below the Point had been raised and moved through the cut-off at 4 o'clock on the afternoon of February 18, by the damming up of the water to the height of 14′ 6¼″ above zero, it is probable that if no masses of ice, and but little water, had passed into the canal under the floating caisson, this backing up to the height of 14′ 6¼″ above Nussdorf would have occurred several hours sooner and would have carried its whole ice-gorge through the cut-off.

But even in case the floating caisson had completely closed the head of the canal, and, in consequence thereof, the water at Nussdorf would have been backed up 1′ 0½″ or 1′ 6½″ higher, that is, to a height of 15′ 6¾″ or 16′ 0¾″ above zero, no danger would have thereby resulted to the Nussdorf dam on the right bank, for this mighty dam resisted the water successfully in the years 1862 and 1871 where it reached the height of 16′ 5″ and 17′ 4½″.

From the preceding it will be seen that the anonymous expert surely does not himself believe in his oracle, and that he only wrote it to create a sensation and to array non-professionals against the improvement.

4. This expert further insists upon it, that in preparing the project the discharge of the stream had not been ascertained, and that even to-day, when the most of the work may be considered completed, the discharge through the constructed cross section is not known. That this assertion is a clear falsehood is undoubtedly apparent to you, esteemed gentlemen, from that which I have already said.

I do not believe that I ought to touch further on the numerous other slips and defects of the anonymous expert, since you, my esteemed associates, have already gained the conviction from the points which I have mentioned that he, either through ignorance, or based upon intentionally incorrect data, made, technically, entirely incorrect, clearly one-sided assertions and conclusions only with the intention of disparaging the work which has been done, as well as the engineer intrusted with its charge, in the eyes of our fellow citizens, without thinking, however, that by so doing he has brought this national enterprise in discredit in foreign countries, and has thus injured the interests of Vienna. This leads me to the conjecture that he is no Austrian, and at least, not a patriot.

If the esteemed Society of Austrian Engineers and Architects should select a committee to gain a thorough understanding of the working of so much of the work as has been executed, I will take the liberty to make a motion that this committee be requested to thoroughly examine the assertions and complaints of this anonymous expert in the four newspaper articles to which I have referred, and to give an opinion thereon.

THE STORAGE OF ELECTRICITY.

By SYLVANUS P. THOMPSON, B.A., D.Sc., Professor of Experimental Physics in University College, Bristol.

From the "Journal of the Society of Arts."

SCIENCE has of late made two advances, the ultimate importance of which it would be difficult to overestimate. Not many months before he was seized with the mortal illness which robbed us too soon of his rare and unique genius, Professor Clerk Maxwell was asked by a distinguished living man of science what was the greatest scientific discovery of the last twenty-five years. His reply was: "that the Gramme machine is reversible." His far-reaching and philosophic mind had perceived that in this phenomenon, which to so many had seemed little more than a curious scientific experiment, lay the principle which, if rightly developed, would render possible the electric transmission of power, and, in the solution of this practical problem, bring about social and economic changes, the importance of which but few of us have even yet begun to realize.

If we could to-night summon up the noble spirit of the philosopher, and ask him to tell us what recent scientific discovery came next in importance to this, I think we should receive the reply, "that a voltaic battery is reversible." The reversibility in the action of the voltaic cell is the counterpart and complement of the reversibility of the Gramme machine; for while the one has solved for us the problem of the *electric transmission of power*, the other has solved for us the problem of the *electric storage of energy*.

The storage of energy in such a form that it shall be available for producing electric currents, and for the electric transmission of power, is a fact of so great importance, both in science and in commerce, that no apology is needed for bringing the subject before the Society of Arts. But the electric storage of energy, which is the end attained, must not be mistaken for the storage of that subtle agent electricity itself. A century ago it was thought that the Leyden jar provided a means of bottling up electricity itself. In one sense this may be true, though the fact remains that, the more carefully we hunt for the charge of electricity condensed in the jar, the more difficult does it become to realize that there is anything there; and it is doubly difficult to find, in the electric *accumulator* or *storage cell*, anything which can be called stored electricity. In electric accumulators, such as those of Planté and of Faure, electric currents are made to do a certain kind of work, which store of work can again yield us currents of electricity. But, as a matter of fact, the particular kind of work done is, as we shall see, quite as much chemical as electrical. Just as in Sir William Armstrong's hydraulic accumulators, water forced into a vessel with a great pressure furnishes a means of storing mechanical power under such conditions that when we let it down it can do work for us; so in the electric accumulator, by which we want to store electric currents, we use a chemical storage, and the chemical work so stored can itself, as it runs down, set up electric currents in our wires and do electrical work for us.

Before dealing with the various systems of electric storage that have been suggested, I purpose to lay down two important general principles. They are as follows:

Firstly, that no kind of storage of energy, mechanical or electrical, is possible, except by doing work in overcoming some force which itself opposes the process.

Secondly, that the action in which work is thus done, must be one that is reversible; that is to say, to which there is an equal and opposite reaction.

ELECTRICAL ACTION AND REACTION.

"To every action there is an equal and contrary reaction." In these words Newton laid down the great fundamental principle of mechanical science. Its application is not limited to such mechanical reactions as the recoil of a gun, the return of a bent spring, or the mutual attractions of the planets, but reaches down into other departments of science. To Newton himself, we owe the simple experiment in which he proved the extension of the principle to magnetic forces. He found the magnet to be drawn towards a piece of iron with a force precisely equal to that with which it drew the iron to itself. It was left to Newton's great contemporary, Robert Boyle, to demonstrate that the same law held good also for the force of electric attractions; an electrified body drawing a non-electrified one towards itself, and being itself attracted with an equal and oppositely directed force.

But Newton himself showed that there existed another and deeper meaning to the law of action and reaction, when he laid down the famous comment* which, though forgotten until unearthed by Sir William Thomson, virtually anticipated the nineteenth century discovery of the theory of the conservation of energy. As understood in the light of modern dynamics, any "action" in which energy is spent and work done is found to have its corresponding "reaction" in the possibility of the energy thus stored being at some later time set free. That particular "action" of an agent to which Newton told us there was still an equal "reaction," when the action was meas-

* "Si æstimetur agentis actio ex ejus vi et velocitate conjunctim," &c. Principia philosophiæ naturalis. This famous scholium is paraphrased as follows by Thompson and Trait ("Treatise on Nat Phil." Chap II., Art. 269):—"Work done on any system of bodies has its equivalent in work done against friction, molecular forces, or gravity, if there be no acceleration; but, if there be acceleration, part of the work is expended in overcoming the resistance to acceleration, and the kinetic energy developed is equivalent to the work so spent."

ured by the product of its momentum into its velocity, was, in fact, nothing other than its *capacity for doing work.*

If you lift a pound of iron to a certain height against the pull of gravitation, the action implies the expenditure of a certain amount of energy, the equivalent of the work done. Precisely an equal amount of work (saving a trifling proportion converted into unuseful work of another kind, namely heat) can the mass of iron do in falling back again; for by its fall it may do the work of raising another pound to the same height.

In the science of electricity and in magnetism the same fundmental principle holds goods. Suppose, for example, energy to be spent in the following action. Let a heavy weight descend over a pulley, and in its descent cause the disc of a Holtz's electric machine to rotate; the work done in this case is electric work, the energy being expended not in moving matter against gravitation or any similar force, but in moving electricity against those electric forces which are continually urging it to run down to the dead level of equal and uniform potential. But our supply of electricity thus provided can itself be made to do work, because it can thus run down and give out in another form the energy expended on it. Only let it be led by wires into the terminal poles of another Holtz machine, and it will drive it round, and by driving it round may be made to lift a weight. The reaction here is the converse of the action, and would be equal but for inevitable waste by friction and dissipation of the electric charges.

Another instance of electric action and reaction is afforded by the reversibility of dynamo-electric machines, such as that of Gramme, as mentioned at the outset. The Gramme machine can be used either as a generator or as a motor. If driven by the power of a steam engine or a gas engine, or by wind power or water power, or hand power—in short, by any mechanical means whatever—it generates powerful currents of electricity, which may be used for producing electric lights, or any other kind of work that an electric current can do; the currents of electricity being due to the rapid movements of coils of wire fixed upon a rotating armature across a field of magnetic force, excited by the currents themselves in the machine. If, on the other hand, currents furnished by any suitable source are led by wires into the coils of a Gramme machine, these currents will drive it round, and will expend their energy in producing mechanical rotation, enabling the machine to be used as a motor.

Here I may remark, in passing, that the reversibility of the Gramme machine affords a means of electric, or rather of electro-mechanical storage. Suppose we want to store electric currents. Set them to drive a Gramme machine, and let the Gramme machine, by means of a pulley, gradually wind up a very heavy weight. If, subsequently, we let the weight descend, it will drive the Gramme machine, and will generate currents as it runs down.

ACTION AND REACTION IN VOLTAIC CELLS.

We now pass to the more immediately important case of the reversibility of the voltaic cell, and of its chemical and electrical actions.

In the ordinary voltaic cells, currents of electricity are produced at the expense of a certain consumption of zinc and of acid. These materials may be regarded as the fuels of electric currents, just as coke and coal are the fuels of steam power. Like those fuels, they represent a store of energy. Everybody knows that when two bodies attract one another (as for instance the earth attracting a stone), and we do work in separating them, they posses the power of rushing together again, and of doing work; and, therefore, when so separated, may be said to represent a store of potential energy. This is equally true in the case where we do work against the atomic attractions known as chemical affinity. Zinc has a certain chemical affinity for oxygen. To separate an atom of zinc from one of oxygen requires energy to be expended. When thus separated they have the chance of doing work in reuniting, this work generally appearing in the form of heat. When a piece of coal is burned, that is to say, is permitted to unite chemically with oxygen, its store of energy runs down, and manifests itself in the evolution of heat. A piece of coal represents a store of energy. So does a bag of hydrogen gas. So does a piece of zinc;

for zinc can burn directly and give out heat; or may burn indirectly by being dissolved in sulphuric acid, also giving out heat. A Daniell's battery represents a store of energy. A pinch of gunpowder also represents a store of energy. The amounts differ, it is true; and the rate at which some of these stores can be made available for use, also differs widely in the different cases.

An ounce of coal represents an amount of energy which, if entirely expended in doing work, would raise 695,000 pounds one foot high against the force of gravity, or would do 695,000 foot-pounds of work. In an ounce of gunpowder is stored about 10,000 foot pounds of energy. An ounce of zinc represents a store of only 113,000 foot pounds. An ounce of copper represents a store of about 69,000 foot pounds only. An ounce of hydrogen gas will yield, by combining with oxygen, 2,925,000 foot pounds of work. Joule first showed us how to make use of facts like these, in calculating by its mechanical value the electric power of voltaic cells. Let us apply these considerations to the storage of energy in any ordinary voltaic cell—say, for example, the Daniell's cell used in telegraphy. In this cell we have certain liquids containing zinc and copper, chemically dissolved in sulphuric acid, and into these liquids dip a plate of zinc and a plate of copper. The zinc plate slowly dissolves away, and at the same time, metallic copper is gradually separated out of the solution, there being about $1\frac{1}{20}$ ounce of zinc consumed for every ounce of copper deposited. Now, to separate an ounce of copper from its solution in sulphuric acid, requires 69,000 foot pounds of energy to be spent upon it; and as $1\frac{1}{20}$ ounce of zinc represents a storage of 118,650 foot pounds, the consumption of this weight of zinc is enough to provide the 69,000 foot pounds needed to separate the copper, and to leave a surplus of 49,650 foot pounds. It is this surplus which goes to maintain electric currents in the circuit, and to do electric work.

But, as we have remarked, the voltaic cell is reversible. If we take such a cell, and by means of some superior electromotive force drive electric currents back through the cell, the whole action will be reversed. Copper will be dissolved, and zinc will be deposited. The copper in dissolving will help the process by giving part of the necessary energy, and our currents will thus once more give us back pure zinc, and so separating out the zinc we do work and actually store energy.

In modern treatises on heat, frequent reference is made to an ideal and wholly impossible sort of engine known as Carnot's reversible engine, which is supposed to have the power of being worked backwards, not however in the engineer's sense of reversing the motion, but in a much more striking sense. Carnot's engine, like every other engine, is supposed to act by heat passing through it from a boiler to a condenser, part of the heat so passing through being converted into work, and the ideal reversibility consists in the suggestion that if the engine could be driven backwards by spending mechanical power upon it, the work should be converted back into heat, and the heat should be pumped back from the condenser into the boiler, and from the boiler back into the fuel.

But while Carnot's reversible heat-engine exists in the ideal state, we have in the voltaic battery a real reversible engine; for it is possible here to pump back these electric currents into our cell, and even to go further, and to pump into its metallic state the zinc, the fuel which had been consumed in the cell.

Now, while we are thus using currents to separate the zinc from its solution, the zinc is all the while tending to reunite.

Its tendency so to reunite—its chemical affinity, so called—manifests itself as a counter-electromotive force; this counter-electromotive force being technically known to electricians under the name of "polarization." The name is not a happy one, but will do if we once understand its meaning. Polarization is the electric reaction at the poles or electrodes of a cell, and is of the nature of a counter-electromotive force. To send a current through a cell, we must apply an electromotive force at least as great as that to which the polarization can attain, or we shall not overcome the tendency of the separate elements to reunite. In fact, it is in overcoming this polarization force, that we do the work of storage. We do electro-chemical work by overcoming electro-chemical forces, just as we do mechanical work by overcoming mechanical forces. In every case the storage is effected by overcoming some reaction. If weights that have been lifted, and springs that have been bent, and metals that have been chemically separated, and did not tend to return to their former condition, none of these could serve as vehicles or instruments for the storage of energy. Without reaction storage of energy would be impossible.

It will next be convenient to glance briefly at the principal laws affecting the counter-electromotive forces of polarization, that is to say, those electromotive forces which are developed by currents at the poles of the cells, and which tend to oppose a reaction to the currents that evoke them.

LAWS OF POLARIZATION.

To tear away an atom of any element from its compound with an atom of another element, requires the use of a definite amount of electricity, and necessitates further that this electricity should be urged forward with at least a certain minimum of electromotive force. Take for example the case of the decomposition of water by the electric current. To tear away a single gramme of hydrogen from the oxygen with which it is combined requires no less than 95,050 webers ("coulombs") to flow through. But these liberated and separated gases are in one sense a store of energy, and would, if allowed to combine together (by burning), produce heat. Their "affinity" for one another is very great, and the electric current has to do a considerable amount of work in tearing these two kinds of atoms away from one another. To see what this work amounts to, let us inquire how many units of heat they would evolve in burning. Careful measurements by Favre, Andrews, and Julius Thomsen, show that 34,000 calories of heat would result. Now, the work done to separate the gases is, of course, equal to the work they would do by rushing together. The affinity of the gases manifests itself as a reaction against the electromotive force of the current employed to separate them. This reaction is itself a counter electromotive force. When we overcome an opposing electromotive force by pushing a certain quantity of electricity from one point to another against its reaction, we do work just as truly as when we overcome an opposing mechanical force by pushing a certain lump of matter from one point to another against its resistance. In the particular case of the decomposition of water, the opposing electromotive force of polarization has a magnitude when expressed in the proper units of 1.49 volts. It is possible, when we know how much heat would be evolved by the combination of an equivalent of any substance with oxygen, to calculate the amount of the electromotive force that would have to be applied to tear away that substance from its combination with oxygen. Or, again, suppose we know that of two elements one will, when combining with its equivalent of oxygen, give out more heat than another, then we know that it has a greater affinity for oxygen, and, from the difference between their "heats of combination," we can calculate the surplus of electromotive force that we should have to apply to tear away one of these two from oxygen, and to put the other in its place.

In the accompanying table are given, firstly the equivalent heat values of the various metals when oxydized and dissolved in sulphuric acid. In the second column are given the electromotive forces that would be needful to tear away these elements from oxygen, or with which they tend to unite with oxygen—the value, in fact, of the electromotive force which measures electrically the chemical affinity of each of these elements for oxygen.

The order in which these metals are arranged is, in fact, nothing else than the order of oxidizability of the metals (in the presence of dilute sulphuric acid); for that metal tends most to oxidize which can, by oxidizing, give out the most energy. It also shows the order in which the metals stand in their power to replace one another (in a solution containing sulphuric acid). Thus, if copper be put into a solution of platinum the platinum is reduced, and some of the copper dissolves, evolving heat. If, however, zinc be placed in a liquid containing a copper compound, it displaces the copper, throwing down the latter as a metal and itself dissolving, while its surplus stored energy runs down as heat. In this order, too, the lowest on the lis.

TABLE OF ELECTRO-MOTIVE FORCE AS CALCULATED FROM THE HEAT OF OXIDATION OF THE CHEMICAL EQUIVALENT (H=1 GRAMME), AND AS OBSERVED BY DIRECT EXPERIMENT.

Name of substance.	Heat value.	E. M. F.	Electro-motive force observed in dilute sulphuric acid				
	Calories.	Volts.	With oxygen.	With platinum.	With ozone.	With peroxide of lead.	With zinc.
Potassium	69,800	3.04	..	3.17 (Bf.) 2.484 (Wh.)	..	3.528 (Wh.)	—1.144 (Wh.)
Sodium	67,800	2.95	..	..	..	..	..
Zinc	42,700	1.862	1.873	1.546 (Po.) 1 439 (Wh.) 1.67 (Bz.) 0.637 (R.)	..	2.448 (Wh.) 2.98 (J.)	0
Iron	34,120	1.570	..	..	..	..	[0.600 (A. & P.)]
Hydrogen	34,100	1.493	? 1.64 (Ta.)	0.86 (R.) 0.877 (Bz.)	1.9 (R.) 2.1 (Wh. Po. Sv.) 2 3 (Bf. Ta.) 2.265 (Ba. Bz.)	? 2.78 (Pl.)	..
Lead	25,100	1.133	..	..	..	2.88 (Pl.)	0.21 (A. & P.) 0.55 (D.L.R.)
Copper	18,760	0.818	0.74 (R.)	0.550 (R.)	..	..	0.953 (Po.) 1.079 (L. C.) .978 (L. C.) [0.75 (A. & P.)]
Silver	? 9,000	..	..	..	..	..	
Platinum	7,500	0.327	..	0	1.21 (R.) 1.04 (R)	0.6 (R.) 0.75 (R.) 0.90 (Wh.)	1.546 (Po.) 1.489 (Wh.) 1.67 (Bz.) [0.981 (A. & P.]
Carbon	? 2,000	..	..	..	1.435 (L. Swj.) 1.18 (R)	..	[1.096 (A. & P.)]
Oxygen	0	0	0	..	..	..	..
Nitric peroxide	—6,000	—0.29	..	..	..	..	1.97 (Bf.) 1.95 (L. C.) 1.96 (Sb.)
Chromic peroxide	—7,195	—0.31	..	..	..	..	2.028 (Sb.)
Manganese peroxide	..	..	..	—0.54 (Wh.) —1.101 (R.) —0.128 (R.) —0.404	..	0.504 (Wh.) 0.426 (J.)	1.944 (Wh.) 2.55 (J.)
Lead peroxide	..	..	..	—0.6 (R.) —0.75 (R.) —0.90 (Wh.)	..	0	2.448 (Wh.) 2.98 (J.) 2.1 (D'A.)
Silver peroxide	..	..	..	—0.7. (R.) —0.86 (R.)	..	..	..
Hydrogen peroxide	—10,800	..	..		..	..	..
Ozone	—14,800	—0,645	..	—1.04 (R.) —1.21 (R.)	0	.	..

D'A., D'Arsonval; Ba., Bartholi; Bf., Buff; Bz., Beetz; L. C., Latimer Clark; D.L.R., De la Rue; J., Joule; L., Lenz; Pl., Planté; Po., Poggendorff; R., Raoult; Sb., Sabine; Sv., Svanberg; Swj., Saweljew; Ta., Tait; Wh., Wheatstone; A. & P., Ayrton and Perry (whose observations, being made with an electrometer for contact in air, are placed in square brackets, as not being, like the rest, observations on the electro-motive force in sulphuric acid.

first, are the metals deposited by an electric current from solutions containing two or more of them: for that metal comes down first which requires the least expenditure of energy to separate it from the elements with which it was combined.*

REACTION OF PEROXIDES.

In the preceding discussion, oxygen has been taken as the standard electro-negative substance. But in point of fact there are substances more highly electro-negative; that is to say, substances which when made to combine with a metal such as zinc would give out together a larger amount of heat than zinc does with oxygen. Chief amongst those substances are chlorine and the haloids, the peroxides of the metals manganese, lead, and silver; such peroxidized bodies as chromic, perchloric, and permanganic acids, the peroxide of hydrogen, and ozone. If, for example, zinc be caused to combine with an equivalent of peroxide of lead, more heat is evolved than by the mere oxidation of zinc by free oxygen gas. It is clear then that in the unstable chemical aggregation of the peroxide we have a store of energy which can be utilized in giving us voltaic cells of still higher electromotive force. The highly electro-negative (or oxidizing) property of the brown peroxide of lead was discovered in 1835 by Munck af Rosenschöld, who describes it as being the most highly electro-negative substance known, being superior even to the peroxide of manganese which Volta found so highly electro-negative. There are, as a matter of fact, several oxides of lead, containing least oxygen of all these oxides; *minium* or red lead, containing a greater proportion; and the *brown* peroxide, with the highest proportion of oxygen, the best conductor and the most highly electro-negative of them. The peroxide of silver is still more highly electro-negative. This power can easily be verified by making a small voltaic cell with a pair of plates, the one platinum covered with a film of peroxide of lead, the other of zinc. One such cell will decompose water, which a copper-zinc pair will fail to do. For to do this requires, as may be seen by the table, an electromotive force exceeding 1.493 volts, this being the measure of the affinity of hydrogen for oxygen. The platinum-zinc pair would have an electromotive force of only 1.044 volts, while that of a peroxide of lead-zinc pair is about 2½ volts.

MINIMUM ELECTROMOTIVE FORCE FOR CHARGING.

The electromotive force of polarization in a cell, evoked there by the passage of a primary current through it, will depend upon what circumstances are produced at the two electrodes by the passage of the current. In the case of all ordinary liquids and metallic solutions, the products are known.

For each electrolyte there is a minimum electromotive force, without which complete decomposition cannot occur. For water, for example, this minimum is 1.495 volts. If the current be of less electromotive force than this minimum, the action may begin, but the charging current will be stopped the moment the opposing electromotive force of polarization has risen to an equal amount. It is for this reason that in charging a Planté cell, or a Faure cell, we must use at least two cells of Grove's or Bunsen's battery, or at least three cells of Daniell's battery.

The chemical work that is done in any

* The calculation of the figures in the second column (the electromotive forces, from those of the first column the number of the calories of heat evolved by the oxidation and solution of that amount of the substance that is chemically equivalent to one gramme of hydrogen) is effected in a manner originally suggested by Mr. Joule and Sir William Thomson. The number of heat units or calories is ascertained by direct experiment in the calorimeter in the manner familiar in the researches made on heat of combination by Favre, Andrews, Julius Thomsen, and Berthelot. Now, Faraday showed that the quantities of metals concerned in the electro-chemical operations in voltaic and electrolytic cells are proportional to their chemical equivalents; and the later researches of Weber, Kohlrausch, Mascart, and Alder Wright have shown that this proportionality can be expressed by a numerical coefficient, which we may call the "Faraday coefficient," and which will depend on the unit in which electrical qualities are expressed. If we take the coulomb (or "weber," as the unit of electric quantity, then the Faraday coefficient is 0.000105; or, in other words, each weber (or coulomb) of electricity which passes through a cell will involve the liberation or combination of 0.000105 grammes of that element, whose chemical equivalent is 1, and proportionally more of those whose chemical equivalents are greater. The heat value of the chemical work done by one weber (or coulomb) of electricity, in removing or depositing any metal in any cell, is obtained by multiplying by 0.000105, the figure standing opposite the metal in question, in the first column of the table. These heat values are turned into absolute units of work by multiplying by Joule's mechanical equivalent of heat, which is, in the centimetre-gramme second system of units, equal to 41,530,000, or 41.53×10^6. But the work done in moving a unit of electricity against the reaction in a cell measures the power of that cell to react electrically, or, in other words, measures its electromotive force relatively to oxygen, which is taken here as the standard electro-negative substance. These electromotive forces will be expressed in terms of the appropriate of electromotive force, the volt.

secondary battery, or electrolytic cell, is proportional to the strength of the charging currents, to the time it lasts, and to the effective minimum electromotive force of polarization in the cell itself. It is not increased by increasing the electromotive force of the charging current much beyond this value; for though a higher counter-electromotive force may be temporarily called out, the work done against this added opposition is wasted in local heat, which is detrimental to the power of the cell. The cells should be charged with only just sufficient electromotive force to overcome their reaction. To charge a Planté cell, two Bunsen cells—not twenty—should be used. The storage will be slower, it is true, but it will be more economical by far.

STORAGE POWER LESSENED BY HEAT.

Heat diminishes the counter-electromotive force of the cells during charging; it therefore diminishes the amount of chemical work done in charging them, and diminishes the amount of charge thereby stored. Secondary batteries should be kept as cool as possible during charging. A simple experiment in proof of the diminution of polarization by rise of temperature is the following. Let a single Grove's cell be connected with a water-voltameter: no gases are evolved until the voltameter is heated to near boiling, when the gases come off freely. Bartoli examined the electromotive force of polarization in a cell containing sulphuric acid with electrodes of platinum, and found it to be twice as great when the liquid was at 5° C as when raised to its boiling point. Beetz and Robinson have independently investigated the same effect, and their results agree precisely. Beetz found the polarization 2.216 volts at the ordinary temperature of 20° C, and as the temperature was raised it fell off; gently at first, more rapidly afterwards, till at 100° C. it was only 1.904 volts.

Temperature.	E.M.F. (Beetz).	E M.F. (Robinson).
16°C	2.216	
20°	..	2.216
30°	..	2.194
43°	..	2.148
53°	..	2.105
57.5°	2.101	..
60°	..	2.095
80°	..	2.040
94°	1.960	..
100°	..	1.904

IMPORTANCE OF SUFFICIENT CURRENT DENSITY.

The influence of the polarization force of a cell of the size of the plates used as electrodes relatively to the strength of the charging current has also been investigated by several experimenters, amongst them Crova, Poggendorff, and Bunsen, and more recently by Bartoli and Blondlot. It is found that the degree to which a counter-electromotive force or polarization force is set up depends very greatly on the quantity of current per unit of surface of the electrodes employed. If the current be weak, and the electrodes large, the polarization never reaches its maximum. On the other hand, if the electrodes be very small surface, and the current a strong one, the polarization may attain abnormally high values. Thus Buff, electrolyzing water with small platinum points, found the counter-electromotive force to be no less than 3.57 volts. The difference between this and the minimum value of about 1.493 must be accounted for by the fact that the state of the liberated products varies with the condition of liberation. With greater "current density"* the gases liberated by decomposing water are no longer simple oxygen and simple hydrogen. With greater current density, a greater proportion of the oxygen comes off in the more highly electro-negative condition of ozone, and more peroxide of hydrogen forms also round the anode, whilst at the kathode, the hydrogen which is evolved possesses in unusual degree the active properties attributed by chemists to "nascent" hydrogen" that is to say, a larger proportion of it probably is, at the moment of liberation, in some abnormal allotropic condition, bearing the same kind of relation to ordinary hydrogen as ozone bears to oxygen. The allotropic hydrogen is more oxidizable; the ozone more ready to oxidize. Their union would evolve more heat than the union of equal weights of ordinary hydrogen and ordinary oxygen. It requires greater electromotive force to keep them apart; their own tendency to unite is greater. J. Thomsen

* This term means "the amount of current per unit of surface of the electrodes," and is calculated for either electrode (in the simple case of parallel plates), by dividing the total strength of the current in webers (*amperes*) by the area of that electrode in square centimeters.

has even measured the heat value of ozone as compared with oxygen, and it takes its place in our table of elements at the bottom, below the peroxides, though chlorine and the haloids would be still lower on the list if they came within the scope of present considerations.

It follows from the above argument, that if we wish to make our storing cells exert their highest possible reaction, we must store them, using a current whose strength (or quantity) is proportioned to the size of the cell. If we use too weak a current, the maximum polarization, and therefore the maximum efficiency, will never be attained. This is one of the rocks on which amateur constructors of storage batteries have come to grief. The current density* is a most important consideration, especially in the early stages of the formation of the cells. It certainly should not be less than 50 milliwebers per square centimeter of surface in the cell.

EFFECT OF STATE OF SURFACE.

Again, the state of the surface of the electrodes has much to do in determining the state in which the gases are liberated, and the resulting polarization force. Svanberg, in electrolyzing water with copper electrodes, found the polarization to be .72 volts with smooth plates, and only .47 with corrugated plates. Poggendorff, using platinum plates, found the maximum polarization to be—with bright surfaces, from 2.28 to 2.50 volts; while with surfaces platinized, *i.e.*, coated with a black, powdery deposit of platinum, the polarization in cells, like those of Planté and Faure, where the original surfaces of the plates of lead are coated with thick films of peroxide, or of reduced metal, these considerations do not apply, except for the first operation of charging. Indeed, I have found, experimentally, that there is a gain in scratching the leaden surfaces before forming the coating of peroxide; the coating is more adherent, and the effective surface somewhat greater; advantages beside which the greater preliminary waste of liberated gases on first charging is comparatively trivial.

We will next take a brief historical glance at the various stages in the invention and perfection of accumulators or storage batteries.

HISTORICAL SUMMARY.

Within one year after the discovery of the pile by Volta, two very important observations had been made. Nicholson and Carlisle, in 1800, discovered that the current so produced could decompose water;* and in 1801 Gautherot discovered that the wires of platinum or of silver which had been employed to thus decompose salt water acquired, and retained after being detached from the pile, the power of yielding a transient current, as could be proved by their efficacy in causing muscular contractions in a frog's leg, and in yielding the so-called galvanic taste. This is the phenomenon afterwards denominated "the polarization of the electrodes." It was found to consist in a peculiar state of the electrodes which manifested its presence, even before the exciting current of the pile was cut off, by producing an enfeebling reaction against that current, the polarization current being in a direction which opposed the exciting current. The phenomenon is well known to all electricians, and occurs not only in electrolytic cells, but in the cells of the voltaic batteries, where the liberation of hydrogen bubbles is accompanied by an opposing reaction of the same kind. Indeed, the difficulty with batteries has been to get rid of the polarization.

In 1803, Ritter, of Jena, reobserved the same phenomenon, using wires of gold; and perceiving the importance of this reaction, he constructed a secondary pile which we will presently describe.

The phenomena of the secondary currents due to polarization were further investigated by Volta, Marianini, Davy, Grotthuss, De la Rive, Sinsteden, Becquerel, Schœnbein, Matteucci, Grove, Faraday, Buff, Beetz, and others. Mat-

* Crova, and more recently Bartoli, have given exact formulæ, by which to express this important relation. Let P represent the E.M.F. of polarization at any time: it can be expressed as a function of the possible maximum polarization and of the density of the current. Let A be this possible maximum E.M.F.; s = the surface (supposed uniform), q the time t (supposed short), then

$$P = A\left(1 - 10^{-a\frac{q}{s}}\right)$$

where a is a constant (8,400 circ). This may be interpreted as follows: The polarization falls short of its possible maximum by an amount the logarithm of which is inversely proportional to the current density.

* Water had been previously decomposed by discharges from an electric machine in 1789, by Paetz van Troostwyk and John Cuthbertson.

teucci and Grove in particular studied the reaction currents set up by the presence of uncombined gases at the electrodes, and the latter constructed a well-known "gas battery." In 1869, M. Gaston Planté brought out a secondary battery constructed of lead plates dipping into sulphuric acid, and in a remarkable and valuable series of classical researches, he investigated the phenomena of their action. More recently, modifications of the Planté accumulator have been suggested by M. Camille Faure and M. A. de Méritens. These various systems will be described in detail presently. Professors E. J. Houston and Elihu Thomson, of Philadelphia, have made the suggestion which embodies the principle of reversibility in the case of the Daniell's cell. They place two horizontal copper plates in a cell containing sulphate of zinc in strong solution. To change this cell a current is sent through it from the top plate downwards. The upper plate or anode dissolves, forming a solution of sulphate of copper, which, being specifically lighter, floats on the sulphate of zinc. On the lower plate, metallic zinc is deposited; so that, when charged, this battery is merely a "gravitation Daniell" battery. It will afterwards yield a current so long as there remains any zinc in the metallic state, or so long as there exists a chemical difference between the two electrodes. This suggestion has been modified by M. d'Arsonval, who uses an electrode of lead, or of carbon covered with leaden shot along with an electrode of zinc in sulphate of zinc. In this case, when the cell is charged, zinc is deposited upon the zinc plate, while the lead becomes peroxidized.

Other suggestions have come still more recently from M. J. Rousse, who proposes the use of ferro-manganese, and of palladium as electrodes. The advantages offered by the former alloy over zinc do not appear to be great; and the cost of the latter metal is so enormous as to render suggestion valueless for practical ends.

RITTER'S SECONDARY PILE.

Ritter discovered the possibility of secondary voltaic action while studying the chemical action of electric currents upon liquids. He employed a large voltaic pile as his source of electricity, and observed, not only the decomposition of water into oxygen and hydrogen, but the phenomena of formation of peroxides, and of the deposition of metallic films at the anode and kathode respectively, when metallic solutions were employed. He found that his gold wires, after becoming covered respectively with film, if separated, oxygen and hydrogen could set up violent contractions in a frog's leg. He further investigated the phenomenon with different kinds of wires, and found platinum to yield the best result: gold coming next in order, then silver, copper, and bismuth. With lead, zinc, and tin, however, he obtained no result. He further showed that even after having been removed from the water and dried, the pair of gold wires retained their activity, and when afterwards plunged into water yielded a current in a direction opposed to that of the pile, by which they were originally rendered active.

One remarkable experiment of Ritter's found its way into English journals. Ritter took a *louis d'or*, and placing moistened cloth against its two sides, proceeded to pass through this combination a current from a powerful pile. The coin still laid in its wrappings was afterwards found capable of furnishing a current. This led Ritter to propound the view that conductors of electricity, such as the metals, could be charged with electricity; the coin between its metal wrappings being, according to him, the analogon of the Leyden jar lying between its two coatings of tinfoil. He mentions also mercury, carbon, graphite, and binoxide of manganese, as being capable of receiving galvanic charges. "Each of these bodies," he says, "becomes charged upon both its sides, just like the glass of the Leyden jar, and this state of charge, when it exists in such concentration or intensity, as in the foregoing bodies, is perceived as a state of oxygenation on one side, and a state of hydrogenization on the other." He also draws attention to the curious behavior of quicksilver, which, when placed between water and water and included in the circuit of a voltaic pile, shows movements due to changes in surface tension where the films of gas are produced. Ritter advanced to the rather unwarranted conclusion that, since in these cases the charge stored up depended on the pressure of oxygen and hydrogen films produced from the water, there must necessarily be water in all bodies, and that chemical separation always accompanied electric charge.

To produce these effects of galvanic charge upon a larger scale, Ritter constructed a secondary pile (*Ladungs-Saule*), consisting of a series of discs, of one metal—copper—separated by pads of cloth, moistened with a solution of salt, or sal ammoniac. When charged from a voltaic pile of ordinary construction, this secondary pile received a charge, which afterwards enabled it to give a shock to a person touching its two ends with his hands. It would also decompose water, and, in short, reproduce all the effects of the primary pile, but reversed as to the direction of the currents it furnished.

Ritter was not happy, however, in all his efforts to explain what he observed. He founded his arguments on the incorrect supposition that oxygen consisted of water, combined with negative electricity. It was some years before the researches of Volta, Marianini, and Schonbein, placed the phenomena on their true basis; Schonbein adding the very valuable observation that the presence of ozone in the liberated oxygen intensified the secondary electric action.

PROGRESS IN ELECTRO-CHEMICAL KNOWLEDGE.

The researches of Davy, De la Rive, and of Faraday, upon the chemical phenomena of the voltaic cell, showed that the chemical decompositions within the battery were amenable to the same laws as those which took place in an electrolytic cell at a distant point of the circuit. Faraday brought out several most valuable points in his "Experimental Researches." He describes (Art. 750) how, in electrolyzing acetate of lead, "in place of oxygen, or even the gases already described, peroxide of lead now appears at the positive,* and lead itself at the negative pole." In his argument for the chemical theory of the cell, he remarks that while those substances are highly electro-negative, which cannot be oxidized, there is another class of substances still more highly electro-negative, namely, those substances which readily give up oxygen, the peroxide of manganese being more negative than platinum, as Volta showed, and the peroxide of lead being still more negative than that of manganese, as Munck af Rosenchöld had shown. Faraday remarked (Art. 1822) on the good conducting power of the peroxide of lead. He also observed that red lead is more negative than platinum. De la Rive indeed utilized the strong electro-negative property of peroxide of lead in the construction of a cell in which this substance, packed in a porous pot around a platinum strip, served as one pole, zinc being the other. Niaudet, in his treatise on the "Pile Electrique" (published 1878), suggests that red lead (minium) would have answered equally well. In the Bakerian lecture for 1843, Wheatstone announced that he had measured the electromotive force of peroxide of lead against zinc, and had found it to be 2.266 of that of a Daniell's cell (=2.448 volts).

GROVE'S GAS BATTERY.

In 1842, Sir William (then Professor) Grove described the well known gas battery, which was indeed nothing else than a reversible oxygen and hydrogen battery, in which work had first to be done to produce chemical decomposition, electric currents being passed through acidulated water from one platinum pole to another, these currents being of sufficient power to overcome the opposing mutual affininity of the constituent gases, the reaction of these separated gases tending to produce a counter current of considerable power, and manifesting a so-called electromotive force of polarization.

The rationale of the gas battery is simple enough, provided it be once understood that platinum possesses a power, almost unique amongst the metals, of absorbing upon its surface both oxygen and hydrogen gas. When a current is passed between platinum electrodes in acidulated water, the two gases not only rise in bubbles, but form a film at or in the surface of the metal, which

* Professor Adams, commenting on this observation of Faraday's, shows that Faraday thus anticipated Planté in the discovery of the leaden cell. But a Planté cell filled with acetate of lead is almost useless. The fact that peroxides are thus deposited on the anode was thus discovered before Faraday's researches by Nobili, who noticed also the beautiful irridescent colors in the rings of peroxide films deposited on an anode plate opposite a printed kathrode; the phenomenon known usually as *Nobili's* rings.

when so charged behaves differently from neutral clean platinum. The hodrogenized film resembles zinc or some oxidizable metal, and exercises toward clear platinum, and *a fortiori* toward oxygenized platinum, a strong electromotive force. The energy spent by the decomposing current in separating these gases is stored in the gases that are thus separated. In their subsequent reunion, the energy of their separation runs down into some other form; into heat if the gases are merely mixed and exploded together; into the energy of electric currents if the gases are suffered to recombine through the liquid, by the slower and cooler process of slow chemical combination in the cell.

With a gas battery of 50 pairs, Grove produced electric lights, effected various chemical decompositions, and produced shocks which could be felt by five persons joining hands.

PLANTE'S SECONDARY BATTERIES.

M. Gaston Planté, to whom, more than to any other experimenter, the recent advances in the practical construction of storage batteries are due, very carefully re-examined the whole question of the polarization of electrodes, using different metals as electrodes, and different liquids as electrolytes, and found that the greatest effective polarization was produced when dilute sulphuric acid was electroized between electrodes of lead. Similar researches, though less complete, had been made before by Sinsteden, Poggendorff, Daniell, Lenz, and Saweljew, and by Edmond Becquerel. Sinsteden had even obtained from leaden electrodes polarization currents of sufficient power to raise a thin wire to incandescence. These researches had mostly been undertaken with the view of ascertaining the cause why the currents furnished by most of the voltaic combinations then in use fell off so rapidly in strength. The result of these researches was to suggest methods of getting rid of the residual polarization and its tendency to set up an opposing counter current.

M. Planté, however, struck out in an opposite course, and endeavored instead to find the best means of provoking the phenomenon of polarization, in order, as he expressed it, to turn to profit the secondary currents and to accumulate the energy of the battery. He was, therefore, led by his preliminary researches in 1860 to construct a secondary battery consisting of nine cells, in each of which two long and wide strips of lead, separated by coarse cloth, were rolled together in a spiral form, and immersed in dilute sulphuric acid. A few months later he modified this form by placing side by side in a rectangular box two series of lead plates, alternately connected together, each plate being about eight inches long and nine inches high. He recurred afterwards to the spiral form as being more convenient, but replacing the coarse cloth by narrow strips of gutta percha.

But the cells thus constructed were not ready for immediate action. Two clean lead plates give no current of their own; they are only intended to receive and store up what is sent into them from some external source. And at first, while the lead is bright, when a current is sent through the cell from some suitable source, such as three or four Grove's or Bunsen cells, the separated oxygen and hydrogen gases bubble up to the surface, for the most part, leaving only a very small percentage as an adherent film, and, in consequence, yielding only very transient secondary currents. The plate of lead by which the current enters is, however, attacked by the oxygen, and becomes covered by a thin layer of brown peroxide of lead, and this film, though thin, is powerfully electro negative toward metallic lead, and toward the film of hydrogen on the kathode plate. The cell in this condition will therefore produce a current, and in so doing, the peroxide is partially reduced to the metallic condition, and assumes in its reduction a spongy or loosely crystalline texture. If now the cell be again charged, and charged in the opposite direction, the other plate of lead becomes, in like manner, peroxidized, while the hydrogen bubbles are less freely evolved, for the atoms of gas unite as fast as they are liberated, with the oxygen of the peroxide, and reduce it to the metallic condition. Every time the charging current is thus reversed the films of peroxide, or of spongy metal, become thicker, until the lead to a considerable depth is bitten into. And every such operation increases, therefore, the power of the cell to store up in this electro-chemical fashion the energy of the currents sent into it. M. Planté, who minutely describes the process of "forming" the cell, compares it to a sort of electro-chemical *tanning*. The first day, the alternate charging should be done at intervals of a quarter to half an hour, the cell being discharged between each operation. The next day, the duration of the alternate charges may be increased from a quarter of an hour to a whole hour; the day after to two hours. After repose for a week or a fortnight the charges may last several hours; and by the end of several months, the cell will be well "formed;" after which it should, when used, be charged in one direction only, otherwise, the whole thickness of the lead plates will be bitten into and transformed into peroxide.

The electromotive force thus developed in a fully charged Planté cell may be as much as 2.38 or even 2.7 volts; and as the large area and close proximity of the plates diminish the resistance of the liquid to a very small quantity, such cells are capable of furnishing a very powerful current* for a few minutes, and their calorific power is considerable. In fact, they discharge themselves too well, and run down too soon for many purposes. A single cell 10 inches high will, however, suffice to keep a platinum fire, 2 inches in length and $\frac{1}{100}$ inch in diameter, glowing at a bright red heat for three quarters of an hour. The amount of charge will, of course, depend on the size of the plates and on the degree to which the process of "formation" has been carried out. It may be charged by using two or three Grove's or Bunsen's cells, or by the current of a dynamo-electric machine. A single Grove's or Bunsen's cell will partially charge a Planté accumulator, but cannot raise it to its full power, because the electromotive force of such a source is only 1.9 volts, or less than that of the cell at full power. The cells, when in good condition, will retain their charges for many days, though there is a gradual decay in the charge, owing probably to internal electrolytic convection in the liquid. During discharge the current is evolved with great constancy until quite near to the end of the operation, when there is a sudden falling off. This effect is very remarkable, and arises probably from the conditions of internal resistance, both in the peroxide films, and in the liquids. A Bunsen battery of small size and considerable internal resistance will take some hours to charge a cell fully; while a dynamo-electric machine may fully charge it in half an hour; but the rate of discharge will be alike in each case. The secondary battery plays, therefore, a controlling part in the rate at which such actions may go on. I am inclined to think that the well-known action of a damp string in retarding sparks of a Leyden jar, is due to a similar kind of action. Another curious fact concerning Planté's accumulator is that, after having been rapidly discharged, and left to itself, it will presently yield a small residual current; a phenomenon strikingly similar to that of the residual spark in the Leyden jar. In consequence partly of these useless residual charges, and partly also because a fraction of the energy of the charging current is wasted in heat in the cell, there is a loss of about 11 or 12 per cent. between charging and discharging. M. Planté states that voltametric measurements show that of the whole current 88 to 89 per cent. is given back by the cell. According to M. Géraldy a Planté cell containing 1.445 kilogrammes of lead can store 4.983 kilogrammeters of energy, being at the rate of 3.45 kilogrammeters per kilogramme, or 11.329 foot-pounds per pound.

M. Planté has devoted much attention to the effects produced by uniting these secondary cells when charged, in series, so as to augment their effects. By grouping them in a box with a Muller's commutator above them he is able to charge them in parallel arc, and discharge them in series. Twenty cells will thus furnish for a few minutes an electric arc light. With a large battery of 800 cells thus arranged, M. Planté has carried out a number of fine experiments of the highest theoretical and speculative interest, and destined some day to bear fruit in practical applications. He has further devised an instrument, known as a "Rheostatic Machine," consisting of a number of mica condensers connected with a rotating commutator, by which they can

* The E.M.F. being 2.38 volts, and the resistance as small as from 0.12 to 0.018 ohm, the current through a short stout wire may be considerably over 20 webers (*amperes.*)

be charged in parallel arc, and discharged in series, which, when supplied by the large battery of 800 cells, yields sparks 12 or 14 inches in length, and produces effects which otherwise can only be produced by statical (frictional) electric machines, or by the use of the induction coil. He has observed, amongst a host of other wonderful things, a very remarkable case of globular discharge, the exact counterpart on a small scale of the much disputed phenomenon of globular lighting.

APPLICATIONS OF PLANTE'S ACCUMULATOR.

Since 1872, the Planté cell has been regularly used for the operations of cautery. M. Trouvé, the well-known maker of electrical instruments in Paris, has brought out a whole series of little surgical appliances adapted for use with the Planté cell, including little incandescent lamps to illuminate the cavities of the body—as for example to aid the surgeon in operation upon the larynx—and dentists' appliances for destroying the nerves in hollow teeth. By the kindness of Professor W. F. Barrett, of Dublin, I am enabled to exhibit one of these medical cells, and the various appliances of galvano cautery adapted for use with the same. The advantage of employing a secondary cell for such a purpose, is that such cells may be made of a higher electromotive force, and of a smaller resistance than any single cell of any primary battery yet invented.

Mr. Planté, in 1860, suggested that his accumulators might be usefully employed in telegraphy, instead of the voltameters with platinum electrodes as Jacobi proposed, in order to obviate the retardation in the transmission of signals, caused partly by induction and partly by the residual magnetism of the electro-magnets of the instruments. The opposing current set up in the secondary battery which is in the circuit, being in the contrary direction, sweeps out the residual magnetism and the residual static change so soon as the working battery is cut out of the circuit.

Another application brought out by M. Planté is to the purpose of obtaining a household light, which will serve instead of a match box when it is desired to light a candle or a jet of gas. The "Briquet de Saturne," as he has whimsically termed this new fashioned tinder box, is merely a small accumulator charged by four little Daniell's cells, and provided with a "push," that, when pressed, completes the circuit, through a small strip of platinum foil, which glows with a red heat.

At the suggestion of M. Achard, Planté's accumulators have been employed to actuate a brake on a railway train. To work a brake a great power is required for a short time. This can be done by employing large electro-magnets to move the mechanism of the brakes, the electro-magnets being excited by six Planté cells which distribute power to a dozen different brakes. As the charge stored would last but ten days, six Daniell's cells are also added to provide a constant, though feeble, source of current to keep the accumulators charged, and during the instant when the brakes are put on, the six Daniell's add their feeble share to the total effect. More recently M. Trouvé has employed a battery of six Planté accumulators, to propel a tricycle through the streets of Paris, attaining a speed of about 10 miles per hour. The comparative lightness of the cell in proportion to the mechanical power it can evoke in a small electro-magnetic motor, giving a great advantage in this case over a small steam engine. Trouvé has also fitted a small pleasure boat, with a similar apparatus. If very thin laminæ of lead—lead foil in fact—be employed to form the cells, still greater lightness may be attained in proportion to accumulating power, though, probably, at the expense of durability. This possibility has tempted M. Gaston Tissandier to propose to steer, or even propel, balloons or other aeronautical vehicles by electrical means.

M. Niaudet has shown how the Planté accumulator may be utilized in naval signaling. His suggestion is to exhibit flashing electric lights of great brilliancy, but of short duration; the source being a series of accumulators which, during the intervals of darkness are being steadily replenished by a constant battery, or by the currents from dynamo-electric machines. There seems, indeed, no reason why a complete system of signals should not be arranged for ships on the principle of the system of flashing lights, suggested by Sir William Thomson for lighthouses. And there can be no question that were such a system adopted, many collisions at sea might be saved.

Yet another advantage of the system of accumulation, as carried out by M. Planté in his ingenious grouping of the cells, with the rotating commutator described above, is that with only two Bunsen cells as a source of currents, a powerful electric light can be maintained for a short time. For colleges and schools, and scientific lectures, when an occasional flash of electric arc light is wanted for some temporary purpose, without incurring the labor and expense of setting up 50 Grove cells every time, an accumulating battery is of great value.

APPLICATION TO PHOTOGRAPHY.

I would also draw attention to the great value which such an arrangement offers to photographers, who may desire to have at hand a source of brilliant and white light, with small expenditure of capital and of daily labor.

I mention these applications before dealing with more recent forms of accumulator, because there appears to be an amount of ignorance in the scientific world that is simply inexplicable, with respect to the magnificent researches carried on by Planté through more than twenty years, and the variety of useful applications to which his accumulator had been put before even the fame of more recent inventions had been noised abroad—before they had even been made at all.

We now pass to some of the recent modifications of the Planté accumulator, the principal amongst them being those of M. Faure and of M. de Méritens.

FAURE'S ACCUMULATOR.

In 1880, M. Camille Faure conceived the idea of constructing a secondary battery, in which, though the tedious process of "formation" by Planté's process is modified and shortened, the ultimate result is the same, namely, to produce upon lead plates, immersed in dilute sulphuric acid, a coating of peroxide of lead, that can readily be reduced to the loosely crystalline metallic condition. This, M. Faure accomplishes by the device of giving to his leaden plates a preliminary coating of red lead (minium), made up into a paste with dilute acid, and painted upon the surface. At first he adopted the spiral form of cell, the two plates being separated by felt or leather. More recently the rectangular form has been reverted to. The present mode of construction is as follows:—Eleven sheets of lead of such thickness as to weigh about 2 lbs. to the square foot are cut to the size of 12 inches by 10 inches, an ear piece being burned on at one corner. Or six sheets are taken; five of them being twice the above size, and folded double. These are painted thickly with red lead on both sides, and against each side is pressed a piece of felt, the face of which is also thickly coated with red lead; there being about 17 lbs. of lead and 25 lbs. of red lead altogether. These sheets are placed side by side in a water-tight case, alternate sheets being connected together by the projecting flaps. The cell is filled up with dilute acid; the total weight being about 50 lbs. When thus prepared, the cells are "formed" by a process of charging by means of the current of a dynamo-electric machine, the current being sent through them for six or seven days without intermission before they are ready for use. The red lead is reduced gradually on one side to the metallic state, and on the other assumes the condition of peroxide; but the cell does not attain its best condition for some weeks. As it is important that the electromotive force of the charging current should no much exceed that of the cells (2.38 volts), it is usual to charge a number of cells in series. The internal resistance of such cells is stated as being less than .01 ohm. The advantage of this system of construction is not confined to the saving in time of formation; there is the further advantage of thus obtaining a much thicker film of the working substance than in the Planté accumulator; though with the difference that the deposit of peroxide is not so regular in its structure. According to Sir William Thomson, a single cell of the spiral form weighing 75 kilogrammes (165 lbs.) can store 2,000,000 foot pounds of energy, or one horse power for one hour. Their action is more economical, however, when the charge is not drawn upon at this rapid rate. Economy in working is found to accompany slow and regular discharge. Five or six hours is a more economical time for discharge, and then the waste is believed not to amount to more than ten per cent. Sir William Thompson states, that the probable loss of energy in charging is 10 per cent., and in discharging 15 per cent.; but he thinks it will be advisable in practice to be satisfied with less perfect economy than this. According to Reynier, a Faure cell, containing 56 kilogrammes of lead, can store 210,000 kilogrammeters of electro-chemical energy; or at the rate of 3.75 kilogrammeters per kilogramme of lead, or 12.85 foot pounds per pound of lead. According to M. Géraldy, the figure is slightly less, being only 3.28 kilogrammeters per kilogramme, or 10.76 foot pounds per lb. Such a cell, when on short circuit can, I am informed, furnish for ten hours a current of 10 to 14 webers continuously.

M. Faure is now constructing larger cells, of which, by the kindness of Major Ricarde-Seaver, I am enabled to give the following details:—The leaden plates are about 17 inches long by 12½ wide. About 50 pounds of red lead are used; and the sixteen sheets of lead themselves weigh about 20 pounds. The sheets which are to serve as positive electrodes are eight hundredths of an inch thick; those which are to serve as negative electrodes are four hundredths of an inch thick. After being painted with red lead they are folded up, first in parchment paper, and then in felt, and placed in a rectangular box, with narrow strips of india-rubber to prevent contract. Such a cell requires about 16 lbs. of dilute sulphuric acid to charge it. The total weight is about 135 lbs. for each cell. One of these cells, when placed on a circuit of small resistance, in which one of Ayrton and Perry's galvanometers was included, gave the following values of currents:—

For 8 hours	22	webers	=176	weber hours.
" 4 "	21	"	= 84	" "
" 1 "	20	"	= 20	" "
" 1 "	19	"	= 19	" "
Total 14 hours.			229	

or on an average over 20 webers continuously for 14 hours. The discharge went on after this for seven hours more, when it had stopped to five webers.

DE MERITENS' ACCUMULATOR.

Another modification of the Planté accumulator has been devised by M. De Méritens. In this cell the plates of lead are made up of thin laminæ, folded one upon another like the leaves of a book, or more strictly, like the laths of a venetian blind; the whole being soldered to a stouter framework of lead. The object of this arrangement is to secure a greater amount of effective surface. Two such compound plates are set side by side in a box containing acid; no felt or other separating material being used. The plates require "forming," however, by a longer process than in the Faure cell. This accumulator has been highly spoken of, and showed admirable results at the late Electrical Exhibition in Paris. No examples have yet been brought to England, and I am not aware of any exact measurements having been made of their power or capacity. It is, weight for weight, far more powerful than Faure's cell; and therefore, power for power, is of smaller bulk.

OTHER MODIFICATIONS.

In investigating the properties of secondary batteries, I have tried a number of modifications of the Planté accumulator, with varying success. I have found that almost any oxide or hydrate of lead will answer instead of red lead for the purpose of providing, as in the Faure cell, a material to be converted by a process of formation into the peroxide of lead. Litharge answers well if sufficiently finely divided before being painted on. White lead will even answer, but not so well. Litharge mixed with a small proportion of binoxide of manganese works well. The formation is rapid, but at first the electromotive force is not so high as in the Planté cell. It rises, however, as the process of formation proceeds. The binoxide of manganese is not (see table) so strongly electro-negative a substance as the peroxide of lead. Its presence in the final state would lessen the electromotive force. But happily the manganese gradually dissolves into the acid when its function as an agent to assist the lead in peroxidizing is fulfilled, and by changing the acid a few times it is finally eliminated. The most satisfactory cells I have yet tried were made by painting the lead plates with a coat of the brown peroxide itself, which is obtainable in commerce, though its cost is about four times that of red lead or of litharge. I find this process by far the most expeditious for making up cells; as indeed might be expected, since it is obviously a stage towards simplification to put on to the lead plates a coating of the very substance which we desire ultimately to produce there. Examination of the plates of a cell in which the process of formation has only just begun, shows that the lead surface must itself be peroxidized and bitten into before the useful action extends to the contiguous portions of oxide or peroxide painted over it, and in some stages a yellow suboxide, probably essentially litharge, appears to be produced as an intermediate product of the reduction of the oxide at the kathode. Of this intermediate yellow product, however, I can find no trace in well-formed cells. As the reduction and peroxidation of the coating only begins where peroxidation of the leaden sheet has begun, the relation of density to maximum polarization, pointed out in an earlier paragraph of my paper, becomes of extreme importance. Plenty of current, and yet of an electromotive force, only just exceeding the maximum electromotive force of the cell, is the rule for charging in the early stages of formation. Could a spongy lead be produced by any simple metallurgical process—like the spongy iron of Bischoff's filters—it would probably prove an admirable substance from which to form electrodes for accumulators.

COMPARISON OF PLANTE'S AND FAURE'S ACCUMULATORS.

No very reliable comparisons between the accumulators of Planté and those of Faure, or of De Méritens, have yet been made. Seeing that in each of these, when completely formed, the materials are the same—namely, lead and peroxide of lead immersed in dilute sulphuric acid—the maximum electromotive force must be eventually the same in each. The resistance of a cell is simply a question of size and shape. The relative strength of current actually furnished by these cells should therefore merely vary with their dimensions. The presence, however, of the felt, and its coatings of red lead, introduces resistance into the Faure cell, and as some recent determinations of M. Achard show, a Planté cell will heat a greater length of platinum wire, and do its work three times as quickly as a Faure cell, whose surface is of the same amount. One would also expect *a priori* that the layers of peroxide, formed upon the electrode by the working of the current itself, should be more regular, and yields currents with greater regularity than the artificial and more rapidly-formed layers, made by painting red lead upon the surface. On the other hand, M. Faure points out that, taking cells of equal size, a larger proportion of the weight in his cell consists of the working substance. The weight of red lead placed in his cells being, for equal amounts of surface, about 26 times as much as the weight of peroxide produced by a "formation" during two years on the plates of a Planté cell of equal size. If this be so, it would imply that, though its resistance might be greater, and its rate of working slower than the Planté cell, the Faure cell would accumulate twenty-six times as much energy in an equal space. These figures require yet to be confirmed, and they are hardly borne out by the statistics of M. Regnier. Still less do they justify the extravagant pretensions that have been ignorantly set up on behalf of the enormous powers of the Faure cell—pretensions which have been angrily combated, though it is well to note that neither M. Planté nor M. Faure have taken part in this unpleasant recrimination. The Faure cell will do what the Planté cell will not, take in a greater charge, because it has a greater thickness of the working material, and it gives up its charge less rapidly. The Planté cell will do what the Faure cell of equal weight or surface cannot do, namely produce rapid discharges in currents of greater volume; a property invaluable for the purpose of some of the applications already named.

APPLICATION TO ELECTRIC LIGHTING BY INCANDESCENCE.

Faure's cells have already done good work in providing an efficient means of working incandescent lamps, such as those of Swan and Maxim, for domestic purposes. I have the pleasure of showing you to-night the result of passing through two chandeliers of Edison's little incandescent lamps, the current generated by forty of Faure's accumulators. Here are also some of the incandescent lamps of Swan and of Maxim, lit up by the same means. I have to thank the representatives of the various companies for the courtesy that has put at my disposal these means of illustrating my discourse.

Careful and precise measurements have been made by Sir William Thomson and Mr. J. T. Bottomley, using from 20 to 70 Faure cells as a source of current to illuminate some of Swan's lamps.

SWAN LAMP, NO. 1.

No. of experiments.	Cells.	Volts.	Webers.	Volts × webers ÷ 10 = kilogrammeters.	Horse-power.	Candles.	Candles per horse-power.
1	26	56.9	1.21	6.88	.093	11.6	125
2	30	65 5	1.46	9.56	.129	25	194
3	32	70.2	1.64	11.51	.156	42	263
4	33	71.8	1.74	12.48	.170	38	224
5	34	74.1	1.81	13.42	.181	44	243
6	35	76.1	1.83	13.86	.187	55	294
7	36	78.0	1.99	15.52	.210	63	300
8	37	80.3	2.06	16.54	.224	66	295
9	38	81.9	2.06	16.88	.228	76	333
10	39	84 6	2.06	17.43	.235	82	349
11	40	87.0	2.10	18.27	.247	84	340
12	42	90.9	2.17	19.72	.267	102	382
13	44	92.0	2.11	19.96	.270	89	330
14	46	99.1	2.27	21.91	.296	114	385
		Carbon of lamp broke with same power, immediately after the measurement of the light was completed.					

These measurements have shown that the efficiency is very considerable, and that where from 35 to 50 such cells are available, the light produced by one lamp may range from 300 to 400 candles per horse power, the latter being measured as actually consumed in the lamp. The foregoing statistics of one series of experiments are taken from the paper read by Sir Wm. Thomson at the meeting of the British Association at York, September, 1881. From these experiments, it appears that a high degree of economy in lighting by incandescent lamps is really attained. Should the accumulator be further improved, to reduce the percentage of waste between charging and discharging, accumulators will play a very important part in future installations, provided they can be constructed at a prime cost, lower than the present figures.

At the Paris Exhibition of Electricity, Faure's batteries have been doing excellent work. The following details of the separate installations will give an idea how many cells are required for a given number of Swan's lamps:

	Swan lights.	Faure cells.
Vestibule................	28	56
Kitchen..................	4	
Bath room..	2	
Telephone room (No. 7)....	17	29
Telephone room (No. 8)....	18	29
Exhibit of the Campagnie La Force et La Lumieres.	34	56

FURTHER APPLICATIONS OF ACCUMULATORS.

In an article on electric storage, which appeared in *Nature*, on June 2, 1881, I pointed out the usefulness of accumulators in the following words:

"The uses for such secondary batteries may be of three kinds: 1. They may serve as portable supplies of electricity to be left and called for to recharge when exhausted. 2. They may serve to accumulate supplies of electricity from dynamo-electric machines, and store them until required for furnishing electric light or motive power on a small scale. 3. They may serve as equalizers of electric currents in a system in which the supply is liable to fluctuations. Suppose, for example, a dynamo-electric machine is employed to produce electric light. Any least thing which alters the speed of the machine, even for an instant, makes the light flicker and change in intensity; while the breakage of the engine strap would at once cause total darkness. But if a secondary battery of suitable dimensions and power were inserted across the circuit, between the dynamo-machine and the lamp, the inequalities of the current would be greatly modified. When the light was not in use, the battery would store up the current. If the engine failed, the battery would at once put forth its power. It is probably in this direction that the secondary battery will find no unimportant field of usefulness."

Of the first and second of these purposes you have an illustration to-night, this medical Planté cell and these forty Faure cells having been brought to this room charged, for the purpose of showing you their powers. The third possible use has been also emphasized by Sir William Thomson, who, at the September meeting of the British Association, gave details of a scheme of automatic adjustments to make and break the circuit between the dynamo-machine and the secondary battery, so as to guard the former from damage and the latter from waste.

As to portability, for such purposes as domestic lighting the cost and risk of carting the heavy cells to and fro is probably prohibitory. For special purposes, such as those of galvano-cautery already mentioned, the Planté accumulator is certainly superior to the Faure, since it is lighter, and at the same time gives up its charge more rapidly, though its storage power for cells of equal bulk is less than that of the Faure.

MAXIMUM TEMPERATURE ATTAINABLE BY A CELL.

In connection with the subject of obtaining a high temperature by means of a cell, it may not be out of place to point out that the very high electromotive force of these accumulators (about 2.2 volts), exceeding that of any single cell of any other kind, carries with it the possibility of obtaining with such a cell a lower electromotive force. This discovery is due to Lorenz, of Copenhagen, who, in a very remarkable paper published (in *Wiedemann's Annalen*) in August last, upon the relation between the conducting power of metals for heat and for electricity, has shown that the highest possible temperature which a cell can raise any part of its circuit is proportional to its electromotive force. The highest point to which a Daniell's cell, however large, can raise a conductor is, according to Lorenz, 3,327° above the zero of the Centigrade scale. The limiting temperature for a Planté or a Faure cell is 6,927°.

APPLICATION TO BLASTING AND TORPEDO FIRING.

The great calorific power of these accumulators, due as much to their small internal resistance as to their high electromotive force, is doubtless of great importance in the application to the firing of torpedoes and blasts in mining. The special batteries now used might economically be replaced by one or two storage cells provided with a charging battery of half a dozen of Daniell's cells, whose slowly-produced currents could be thus accumulated.

APPLICATION TO PERFECTION OF THE TELEPHONE.

Another application of the secondary batteries which has occurred to me, and which, on a small scale, I have tried with success, is in connection with telephone transmitters. There is still room for improvement in the telephone; at its best the speech it transmits is neither so loud, nor so distinct, nor so free from extraneous sounds, as might be desired. The fault lies almost wholly with the transmitters. They will not transmit loud sounds distinctly. The strength of the currents generated by the Bell telephone, used as a transmitter, is limited by conditions which are wholly distinct from those which limit the possible strength of the currents transmitted by a "microphone," or "carbon transmitter;" my remarks must be understood as applying to the latter kind of instrument. If you put a very strong current on to a microphone, so as to make it, as you think, speak more loudly, the end is not attained. The points of contact get hot; there is a whirring and wheezing heard at the receiving end; and the speech degenerates into confusion. There is then, a practical limit to which the strength of current flowing through a microphonic current can be carried. Some of the transmitters in use employ three or four points of contact, the current being carried through these either in series or in branching arcs. In the first of these two cases, the limitation is only pushed back by one stage. In the latter case, one only of the contacts usually does the real work of transmitting, namely, that whose resistance is least. I propose to increase the power of a transmitter by employing a multiple microphone. so arranged that a fairly strong current shall pass through each point of contact. and that the current through each contact shall be independent of that through the rest. I therefore arrange all the individual microphones in parallel arc, in the line circuit, but provide each with its own battery. A hundred microphones thus united, and simultaneously acted upon by the voice, will each add their own quantum to the total effect in the circuit; and the result will be loud and distinct speech. But a hundred microphones so arranged, each with its own battery, implies two or three hundred cells. Here the secondary cell comes in with great advantage. I propose to use very small storage cells, each consisting of two small leaden plates, or wires, dipping into dilute sulphurid acid, and properly "formed." Two such cells may be connected with each microphone, and the whole, being already arranged in parallel arc in the circuit, can be kept charged by merely placing across the circuit six Daniell's cells, to be switched off when the transmitter is to be used, and switched on again when the transmitter is no longer required. As yet only a small and rough model of this "secondary circuit transmitter" has been made; but it is extremely satisfactory in its action, and promises to be the first of a useful and important application.

APPLICATION TO RAILWAY PURPOSES.

A proposition is now about to receive practical application to light a railway train with Swan's lamps, by means of Faure's accumulators. This is the new Pullman-car train, plying four times per diem between London and Brighton, which will be lit by forty Faure cells. The trial trip is to be arranged in a few days. A train might be contrived to store electricity gradually, by a dynamo-electric machine fixed to the axles of the carriages, and thus to have a supply of electricity, to be turned on when the train passes through a dark tunnel.

APPLICATION TO UTILIZATION OF WIND AND WATER POWER.

And, lastly, though by far the most important of all the innumerable possibilities opened out by the storage battery, is its application to the problem of utilizing and transmitting the energy derived from wind or water power. The difficulty of utilizing water power is that, that it is so often not to be found where it is desired; the difficulty with power is that it fails too often just when it is wanted. The reversibility of the dynamo-electric machine solves the difficulty of the where by giving us a means of electric transmission. The reversibility of the voltaic cell will probably solve the difficulty of the when, by giving us the means of storing energy, when we can get it, until such time as required for use. The accumulator will probably play an important part also in the distribution as well as in the storage of power transmitted from a distance, and thus become the ally of the dynamo-electric machine. It is certain that we cannot, with our diminishing coal fields, long afford to neglect these other sources of natural power. In his Presidential Address to the Mathematical and Physical Section of the British Association, Sir W. Thomson has dealt with this question, and has come to the conclusion that, though tidal power be practically unlimited, it will not pay economically to build tide basins to utilize this power, as the reclaimed land would be of greater productive value, and that, therefore, we must not look to the tides. If I may venture modestly to differ from so great an authority, I would point out that there are cases where no great expense would be incurred in utilizing natural tidal areas as basins, where the area so utilized could not possibly be reclaimed or worked as profitable land, and where the rise and fall of the tide is greatly above the figure which he assumed. The River Avon at Bristol furnishes a case in point. It requires but a few yards of embankment to be turned into an available tidal area. The average rise and fall of tide at the city of Bristol, five miles from its mouth, is 23 ft. According to calculations I have made from the average volume of water displaced up and down each tide, there are no fewer than 20 billions of foot-pounds of energy wasted every year, or enough to charge ten million Faure cells. At the mouth of the river the total annual tidal energy thus running to utter waste cannot be less than 50 billion foot-pounds; and in the rapid currents of the River Severn, with their enormous tides of great volume, the tidal energy must be practically unlimited. A tenth part of the tidal energy in the gorge of the Avon would light the city of Bristol. A tenth part of the tidal energy in the channel of the Severn would light every city, and another tenth would turn every loom and spindle and axle in Great Britain. But the power would have to be not only transformed and transmitted, but stored, to be available for such ends. Accumulators are therefore a necessary feature in any scheme to utilize the intermittent forces of the tides. Whether the present form will prove adequate to the purpose, the future must decide. Probably the present accumulator bears as much resemblance to the future accumulator as a glass bell jar, used in chemical experiments for holding gas, does to the gasometer of a city gas works, or as James Watt's first model steam engine does to the engines of an Atlantic steamer. When the practical accumulator of the future has been built, it will be more easy to say what will be the limit of its applications. There are, as I have sufficiently shown, immense possibilities in store. Electrical railways and electrical tramways are now existing facts. Many months will not elapse—or it will be an eternal disgrace to the first city in the world—before the fœtid and poisonous atmosphere of the Metropolitan Railway is replaced by a pleasant and salubrious air, rich in fragrant ozone; and the like revolution will not be long delayed in many quarters where reform is far less imperative. In all these changes the accumulator will have its part to play. A reserve of electrical energy stored till wanted will be a necessary part of all systems for electric distribution, whether for the purpose of lighting, or for motive power.

In conclusion, I would point out how the invention of the accumulator for storing the energy of electric currents has arisen out of the study of an obscure and unpromising detail in the science of electricity—the phenomenon of so-called "polarization." Regarded by most experimenters merely as a trivial but disturbing fact in the construction of voltaic batteries, to be put down or got rid of by whatever means, it has been developed, and, mainly by the long and patient researches of one man, M. Gaston Planté, and finally by the brilliant idea struck out by M. Faure, been turned into one of the most fertile and promising features in the development of the science. It is the old story over again of the reward which follows patient investigation of unexplored corners and waste places of science. Grand principles and sweeping generalizations are magnificent weapons to the scientific investigator. The principle of the conservation of energy has reaped triumph after triumph; and a kindred generalization in the science of electricity is destined, as I think, to lead to scarcely less important results. But there are other ways of adding to the sum of human knowledge, beside the following out of grand sweeping principles. There are half-forgotten observations, unconnected, unexplained, and often exceptional in character, every one of which has a significance of its own—residual phenomena, every one of which is, to the scientific man, of a value beyond price. He who investigates them patiently may find the clue to their meaning, and reap a rich reward from them. They are the finger posts in the high road of scientific discovery.

DISCUSSION.

The Chairman, in proposing a vote of thanks to Professor Thompson, said that gentleman had gone a long way back for the origin of secondary batteries, viz., nearly to the time of the invention of the voltaic battery itself; there was, however, a very interesting little book, which had been shown at the Paris Electrical Exhibition, a note-book of Galvani's, in which it was recorded that in 1795, *i.e.*, five years before the discovery of the voltaic pile, he had made an experiment, and discovered a secondary battery, and also made use of a galvanometer, which was not quite the same as that which Professor Thompson stated was used by Ritter. The primary battery which he employed was the electric eel, by means of which he gave a charge to the limbs of a frog, and then using the frog as a secondary battery, and himself as a galvanometer, he was able to get a secondary electric discharge. With regard to the vexed question of electromotive force, he was glad to see that there were figures put forward, though there had not been time to go into them, which confirmed the results arrived at by himself with regard to the amount of electromotive force of the Planté cell. The results arrived at by Sir William Thomson show that the electromotive force of the Planté cell lies between 2 and 2½ volts. The development of this subject had been very rapid indeed. Only a little more than four months ago the Faure battery was quite unknown in England; it was in fact shown for the first time in July, when he had the opportunity of showing it at King's College, through the kindness of Mr. Faure, and demonstrating how the electric light might be obtained by its means; but since then its development had been very rapid. With regard to the amount of work capable of being stored up, they had heard of millions and billions of units, which he feared would not convey a very definite idea to the general public; but perhaps the Electrical Congress of Paris had done a little in suggesting names for electrical units, and if instead of hearing of such enormous numbers of foot-pounds in connection with electricity, they could get the work represented by so many "volt-coulombs," putting together the urits of electromotive force and quantity, it would be simpler, and a better idea would be conveyed of what the unit really was.

Prof. Abel, F.R.S., said he had been greatly interested and instructed by this very lucid paper; a more complete account of the very rapid development of this subject could not have been given in so short a space of time. He did not pretend to be a scientific electrician, though he dealt sometimes with the practical applications of electricity, and he had listened therefore with the greatest interest to what Professor Thompson had told them of the recent developments which the secondary batter had received, and was still receiving. As he listened to him, he began to feel sanguine that these applications might be realized. There were some directions in which, if they could obtain a moderately portable battery, which could be re-charged in a reasonable time, he could see applications that would be of the highest importance. He allüded to the illumination of coal mines, a matter in which he was particularly interested; and he did begin to hope that they might before very long realize the sanguine expectations of some philosophers, and that electricity would be used for this purpose. Up to quite recently, he had been very doubtful, for, having seen some of the first attempts, he had had reason to fear that the necessity for conducting wires along the workings, and in places liable to great falls of the roof and various kinds of accident, might lead to injuries, not merely fatal to the illumination, but also, possibly, to the lives of the miners, in consequence of the production of sparks which might ignite the inflammable gases. If, however, they could see their way to transport to the furthermost parts of the mine a convenient form of secondary battery, with which they could work readily with only short lengths of wire, and if small portable lamps could be attached to the men's caps, there would be accomplished what might be considered the most perfect and safe illumination of a mine possible. This he hoped would be done before many years; there were, no doubt, many other directions in which the stored-up energy might be very advantageously used.

Prof. Frankland, F.R.S., said this invention of the storage of electricity was most important in connection with the applications of this force which were being made at the present time. It was a reproach not altogether unfounded, against the dynamo-current as ordinarily produced, that it might, at any moment, fail from the accidents of machinery or other causes; but such failures would be entirely obviated by the aid of a suitable and effective storage battery, of the kind invented by Planté or Faure. He should like to ask Professor Thompson whether, in his numerous experiments on this subject, he had gone at all into the subject of the length of time this force could be kept stored up in the battery. This was an important point, which, he feared, had been a good deal neglected hitherto. He should like to know whether there was any considerable amount of leakage, and, if so, how much, and for what length of time a battery might be expected to retain its charge. He could only conclude by expressing his best thanks for the very able lecture Professor Thompson had given.

Mr. Evans asked if a number of Faure accumulators could be used to store up the power derived from water wheels, so that the wheels of turbines might work during the night, and the power thus stored be used during the day.

Mr. Shoolbred wished to add a word or two in regard to the De Méritens' battery. He had lately returned from a visit to Paris, and he found the form in which De Méritens was now making his battery, in a practical way differed considerably from the form in which they first appeared, and which had been shown on the screen. Each cell consisted of a solid lead, filled in with thin sheets of lead, less than a millimeter in thickness. It was much simpler than either the Faure or the original Planté battery; whether it was as efficient, yet remained to be seen; but the one in the exhibition worked very well. M. De Méritens had informed him that it took from fifteen to twenty days to form the cell, not, as he had understood Dr. Thompson to say, six months. He had hoped to have got one to bring over, but could not do so. With regard to the figures in the table (see p. 211), and which he saw were Sir William Thomson's, he wished to say that, by the kindness of Sir William Thomson he was enabled to repeat the experiments for photometric measurements, with the aid of Mr. Keats, of the Metropolitan Board of Works, who kindly brought over his own photometer, and the candle power came out even higher than as given by Sir William Thomson.

The Secretary said he was happy to announce that he had seen M. De Méritens very recently in Paris, and he promised that he would send over a complete set of his batteries to the Society of Arts, as soon as they were ready in January or February next.

Two further questions having been asked, viz., as to the expense of producing the light, and why the electric energy in the secondary battery was not given off all at once.

The Chairman put the vote of thanks to the meeting, when it was carried unanimously.

Professor Thompson having acknowledged the compliment, said he would answer the last question first, and he might do so by asking another. How was it that a voltaic battery gave off its energy gradually, instead of going off with a bang? You could not get zinc to dissolve at more than a certain rate; nor in the case of the stored battery could you get the peroxide to reduce itself, and the reduced lead to oxidize itself, at more than a certain rate. Besides, if by any possibility, the battery did go on at too great a rate, it would polarize itself—it would begin to reduce the side towards which the current was going, and so bring down the amount of current passing. The rate at which the action went on depended on the conducting power of the lead, its resistance to electricity, and the amount of surface exposed; also on the condition of the deposited substances. A piece of coal did not give up its energy all at once when put into the fire. As a matter of fact, the action at the surface did not go on at more than a certain rate. As to the expense he should not like to give figures which he could not stand by in a court of justice, and therefore he would not give any. At the same time he should like to explain that he believed the expense of the light then shown would be less, considerably, than it would cost to produce the same amount of light by making gas. For a steam engine with the necessary plant to work a small dynamo machine, and the necessary accumulators to store it up sufficiently to give out for four or five hours a light they saw before them, would certainly not cost as much as to have to set up a gas-generating apparatus with a small gasometer, and the pipes to produce gas of equivalent value. When the prime cost was less to begin with, he had simply to consider the cost of maintenance; and he was quite certain that the gas put into a gas engine to work a dynamo machine would produce more light electrically than it would if burned directly. There was now no question on that score. With regard to the water wheels, if they were used to work a dynamo machine for fourteen hours, and during those fourteen hours the electricity was stored up in an accumulator, or a set of accumulators, it would be a much cheaper and better way of obtaining and storing electricity for lighting, or any other useful purpose, than setting up a large dynamo machine to produce the light directly. For instance, in the Savoy Theater they had a large number of lights produced directly from dynamo machines driven by steam engines, and the lights, when they were all on, flickered up and down, on account of inequalities in the driving. If they employed one-fifth or one-sixth of the driving power and worked the engines all day into accumulators in the cellars, he believed they could work the lights not only far more steadily, but far more economically. He had been asked by Professor Frankland what waste there was by lapse of time in these accumulators, and he had made some inquiries that morning as to what happened on a practical scale, and he was told by Major Seaver that he reckoned there was about 10 per cent. per week loss from batteries left idle. As a fact, they really did not yet know the conditions under which the leakage took place, whether by surface conductivity, by electrical convection, or what. There was a certain amount of waste, but, nevertheless, there were cases in which a very considerable amount of the charge had remained for a considerable time. For instance, there was the celebrated box which was sent from Paris to Sir William Thomson, containing four small cells rolled up in spirals, and packed together. When they went to Glasgow they contained the million foot-pounds; they had been partly discharged again and again, and yet they would still work a small lamp, and would give light for many hours probably. Then some of the Planté cells would retain their charge for a long time. The medical cell he had shown them was brought from Dublin by Professor Barrett a short time ago. He had used it in Dublin. It was then sent to him at Bristol, where it was used, and then it came there, and there was a considerable amount of force in it yet, though, unfortunately, in an evil moment they broke the glass, and half the liquid ran out. The Planté cell held its charge a long time, and he did not see why the Faure should not be equally successful. With regard to the De Méritens battery he did not mean to be taken literally when he said it took some six months to get the cells into a working state, but he did think it was a step backwards to use Planté's method of long-continued electrical action, instead of Faure's more rapid process of producing the peroxide from red lead. He must conclude by expressing his thanks to those who had so kindly assisted him, by lending apparatus for the purpose of the lecture.

During part of the evening the room was lighted by a number of Edison lamps, worked by Faure batteries, lent by the Sociéte de Force et de Lumiere. Incandescent lamps by Swan and Maxim were also shown at work.

Weisnegg's Laboratory Stove.—This apparatus, which is installed in the chemical laboratory of the Municipality at Paris, is designed to maintain a constant temperature within it. This is effected by regulating the supply of gas which heats the stove, and the regulation is effected in the following manner. A mercury thermometer tube passes into the stove from the outside, and the rising of the mercury above the height corresponding to the temperatue at which it is desired to keep the stove is caused to partially close the orifice of the gas supply pipe. The result is that the temperature in the stove falls, and hence the mercury sinks to its old level. The stove is lined inside with plaques of earthenware, and a glass door is provided in front so as to allow the evaporations to be watched. While upon this subject of stoves we may mention that Herr Miske, of Dresden, has invented an acetate of soda stove, which is an application of the property possessed by this chemical, of parting with its heat slowly, after having been fused. It will be remembered that certain Swedish railway companies some time ago first adopted the plan of filling their footwarmers with acetate of soda, and fusing it before placing them in the carriages, the result being that the warmers retained their heat very much longer than those filled with hot water. Herr Miske found that by using a mixture of ten volumes of hyposulphate of soda to one volume of acetate, the time of cooling could be still further extended, and constructed a stove in which the heat is supplied by three flat cases of the fused salts placed between two cylinders, the outer of which is perforated with numerous small holes to allow the heated air to escape into the room. The stove runs on castors and can thus be removed from one room to another.

THEORY FOR TURBINE WATER WHEELS.

By GUSTAF ATTERBERG.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

II.

The equations which must be satisfied in calculating the dimensions of turbine wheels will now be given. They are (4.), (16), (23), (24) and (26), which by transformations give the equations required.

A. *For turbines where the water discharges into the air:*

1. When the angles α and β or the value n are known:

$$\cot\alpha+\cot\beta=\frac{\pi}{30}\cdot\frac{r_1 n}{c.\sqrt{\mu}\sin\alpha} \quad . \quad . \quad (27).$$

$$\cot\gamma=m.\frac{\xi_2}{\xi_1}.\frac{B_2}{B_1}\sqrt{m^2(\cot\alpha+\cot\beta)^2-2\cot\alpha(\cot\alpha+\cot\beta)+\frac{1}{\mu\sin^2\alpha}-\frac{1}{m^2}\left(\frac{\xi_1}{\xi_2}\right)^2.\left(\frac{B_1}{B_2}\right)^2} \quad . \quad . \quad . \quad (28).$$

$$\cot\varphi=\cot\gamma-m^2\frac{\xi_2}{\xi_1}.\frac{B_2}{B_1}(\cot\alpha+\cot\beta).(29).$$

$$\frac{V_1}{c}=\sqrt{\mu}\sin\alpha(\cot\alpha+\cot\beta) \quad . \quad . \quad (30).$$

and equation (24) are used.

2. When the angles α and γ are known, then:

$$\cot\varphi=\cot\gamma-\frac{\xi_2}{\xi_1}.\frac{B_2}{B_1}\cot\alpha-\sqrt{1+\cot^2\gamma-\left(\frac{\xi_2}{\xi_1}\right)^2.\left(\frac{B_2}{B_1}\right)^2\left(\frac{m^2}{\mu\sin^2\alpha}-\cot^2\alpha\right)} \quad . \quad . \quad . \quad . \quad (31).$$

$$\cot\beta=\frac{1}{m^2}.\frac{\xi_1}{\xi_2}.\frac{B_1}{B_2}(\cot\gamma-\cot\varphi)-\cot\alpha \ (32).$$

and the equations (30) and (24) are used.

3. When the angles α and φ are known, the equations (23), (30), (32) and (24) are used.

4. If the angle $\alpha=90°$ and the angle β or the value n is known, then:

$$\cot\beta=\frac{\pi}{30}.\frac{r_1 n}{c.\sqrt{\mu}\sin\alpha} \quad . \quad . \quad . \quad (33).$$

$$\cot\gamma=m.\frac{\xi_2}{\xi_1}.\frac{B_2}{B_1}.\sqrt{m^2\cot^2\beta+\frac{1}{\mu\sin^2\alpha}-\frac{1}{m^2}\left(\frac{\xi_1}{\xi_2}\right)^2.\left(\frac{B_1}{B_2}\right)^2}.(34).$$

$$\cot\varphi=\cot\gamma-m^2\frac{\xi_2}{\xi_1}.\frac{B_2}{B_1}.\cot\beta$$

and equation (24) are used.

5. If the angle $\alpha=90°$ and the angle γ is known, then:

$$\cot\varphi=\cot\gamma-\sqrt{1+\cot^2\gamma-\left(\frac{\xi_2}{\xi_1}\right)^2.\left(\frac{B_2}{B_1}\right)^2.\frac{m^2}{\mu\sin^2\alpha}}.(35).$$

$$\cot\beta=\frac{1}{m^2}.\frac{\xi_1}{\xi_2}\frac{B_1}{B_2}(\cot\gamma-\cot\varphi) \quad . \quad . \quad (36).$$

and equations (30) and (24) are used.

The value of B_2 that gives the best efficiency of the wheel is:

$$\frac{B_2}{B_1}=\frac{\xi_1}{\xi_2}.\frac{\sqrt{\mu}.\sin\alpha}{m}\sqrt{\frac{2(1+\cot^2\gamma)}{1+\sqrt{1+\cot^2\gamma}}}.(37).$$

and then are η from equation (24)′ and φ constant values.

If $\cot\gamma=4$, then:

$$\frac{B_2}{B_1}=2{,}58\,\frac{\xi_1}{\xi_2}.\frac{\sqrt{\mu}\sin\alpha}{m} \quad . \quad . \quad . \quad . \quad (37).'$$

6. If the angle $\alpha=90°$ and the angle φ is known, then:

$$\cot\gamma=\frac{\cot^2\varphi-1+\left(\frac{\xi_2}{\xi_1}\right)^2.\left(\frac{B_2}{B_1}\right)^2.\frac{m^2}{\mu\sin^2\alpha}}{2\cot\varphi}(38).$$

and the equations (30), (32) and (24) are used.

7. If the angle α is known and the angle $\varphi=90°$, then:

$$\cot\gamma=\frac{\left(\frac{\xi_2}{\xi_1}\right)^2.\left(\frac{B_2}{B_1}\right)^2.\frac{m^2}{\mu\sin^2\alpha}-1}{2\frac{\xi_2}{\xi_1}\frac{B_2}{B_1}\cot\alpha} \quad . \quad . \quad . \quad (39).$$

$$\cot\beta=\frac{1}{m^2}.\frac{\xi_1}{\xi_2}.\frac{B_1}{B_2}\cot\gamma-\cot\alpha \ . \ . \ . \ (40).$$

and the equations (30) and (24) are used.

B. *For turbines where the water discharges under the lowest surface of the water in the tail race.*

1. When the angles a and β or the value n are known, then:

$$\cot a + \cot\beta = \frac{\pi}{30} \cdot \frac{r_1 n}{c.\sqrt{\mu}.\sin a} \quad \ldots (27).$$

$$\cot\varphi = \frac{\xi_2}{\xi_1} \cdot \frac{B_2}{B_1} \cdot \left(\frac{1}{2\mu\sin^2 a(\cot a + \cot\beta)} - \cot a\right) \quad . (41).$$

$$\cot\gamma = \cot\varphi + m^2 . \frac{\xi_2}{\xi_1} \cdot \frac{B_2}{B_1}(\cot a + \cot\beta)(42.)$$

and the equations (30) and (24) are used.

2. When the angles a and γ are known, then:

$$\cot\varphi = \tfrac{1}{2}\left(\cot\gamma - \frac{\xi_2}{\xi_1} \cdot \frac{B_2}{B_1} . \cot a\right) - \sqrt{\frac{1}{4}\left(\cot\gamma + \frac{\xi_2}{\xi_1} \frac{B_2}{B_1} \cot a\right)^2 - \frac{m^2}{2\mu\sin^2 a}\left(\frac{\xi_2}{\xi_1}\right)^2 \left(\frac{B_2}{B_1}\right)^2} \ldots (43).$$

and the equations (32), (30) and (24) are used.

3. When the angles a and φ are known, then equations (26), (30), (32) and (24) are used.

4. If the angle $a=90°$ and the angle β or the value n is known, then:

$$\cot\beta = \frac{\pi}{30} \cdot \frac{r_1 n}{c.\sqrt{\mu}.\sin a} \quad \ldots (33)$$

$$\cot\varphi = \frac{\xi_2}{\xi_1} . \frac{B_2}{B_1} . \frac{1}{2\mu\sin^2 a\cot\beta} \quad \ldots (44).$$

and equations (29), (24) and (30) are used.

5. If the angle $a=90°$ and the angle γ is known, then:

$$\cot\varphi = \frac{\cot\gamma}{2} - \sqrt{\frac{\cot^2\gamma}{4} - \frac{m^2}{2\mu\sin^2 a}\left(\frac{\xi_2}{\xi_1}\right)^2 . \left(\frac{B_2}{B_1}\right)^2} . (45)$$

and equations (36), (30) and (24) are used.

The value of B_2, that gives the best efficiency of the wheel, is:

$$\frac{B_2}{B_1} = \frac{\xi_1}{\xi_2} \cdot \frac{\sqrt{\mu}\sin a}{m} \cdot \sqrt{2} . \cot\gamma \frac{\sqrt[4]{1+\cot^2\gamma}}{1+\sqrt{1+\cot^2\gamma}} \quad \ldots (46.)$$

and then are η from equation (24)' and φ constant values.

If $\cot\gamma=4$, then:

$$\frac{B_2}{B_1} = 2{,}24 \frac{\xi_1}{\xi_2} \cdot \frac{\sqrt{\mu}\sin a}{m} \quad \ldots (46).'$$

6. If the angle $a=90°$ and the angle φ is known, then:

$$\cot\gamma = \frac{1}{\cot\varphi} \cdot \left\{\cot^2\varphi + \frac{m^2}{2\mu\sin^2 a} \cdot \left(\frac{\xi_2}{\xi_1}\right)^2 \left(\frac{B_2}{B_1}\right)^2\right\} \quad \ldots (47).$$

and equations (30), (32) and (24) are used.

7. If the angle a is known and the angle $\varphi=90°$, then:

$$\cot\gamma = \frac{1}{2\cot a} \cdot \frac{m^2}{\mu\sin^2 a} \cdot \frac{\xi_2}{\xi_1} \cdot \frac{B_2}{B_1} \quad . . (48).$$

and equations (30), (40) and (24) are used.

Is $\mu=1$, then is:

$$\beta = 180° - 2a.$$

If when the turbine is calculated, and the values of ξ_1 and ξ_2 are found to be not satisfactory, then without any more change of the details of the wheel, better values of ξ_1 and ξ_2 may be assumed, if at the same time the values of B_1 and B_2 are changed, so that they become $B_1' = \frac{\xi_1}{\xi_1'} . B_1$ and $B_2' = \frac{\xi_2}{\xi_2'} . B_2$, because the product of B and ξ is in all equations and they are never separated from each other.

Turbines constructed without consideration of the best efficiency may often be used in practice, for instance, when a given velocity of the wheel is wanted. Therefore the equations that must be used in calculating these wheels have been mentioned. For wheels where $a=90°$ the angle φ cannot be 90°, as the wheel then would have an immense velocity and the angles β and γ would be equal to zero. The best way to calculate these wheels is to assume the value of $\cot\gamma$ to be as great as it can be made in practice, as the greater this value the better is the efficiency obtained. A good value of $\cot\gamma$ is $\cot\gamma=4$. For these wheels equations (37) and (46) should be used, as by their use the best efficiency is obtained.

The form of the vanes in the wheel.—The vane ought to be constructed with much care as upon its form depends the flow of the water in the wheel. Its form is arbitrary between narrow limits, but it cannot be assumed at will if a given flow is desired. The number of the vanes ought to be the least possible, because the water then gets a more uniform flow. Fig. 8 shows a wheel with only four vanes.

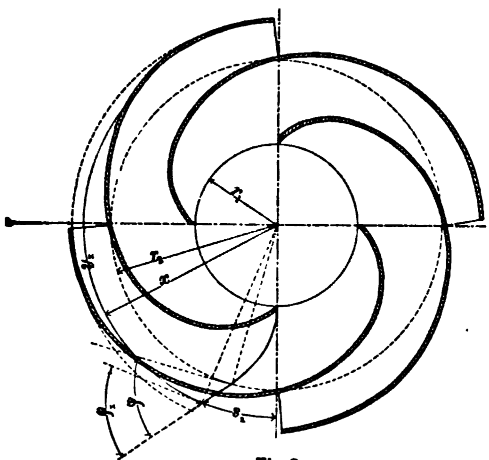


Fig. 8

From this figure it will be seen that the vanes ought to be lengthened, so as to enclose the water till it discharges at that circumference of the wheel which corresponds to the radius r_2. For wheels where r_1 is larger than r_2 many vanes must be used, because for those wheels it is advantageous to make the difference $r_1 - r_2$ as small as possible.

In order to obtain a good form for the vane it is best to construct it from the form of the curve which one particle of water describes when it passes through the wheel.

The volume Q of water flows through the wheel per second. The time required for a particle of water to pass through the wheel between the circumferences which have the radii r_1 and x is:

$$t_x = \frac{\text{The volume of water enclosed between the radii } r_1 \text{ and } x}{Q}$$

If—see Fig. 4—the surface $a_1\, a_1\, d_1\, d_1 = A_x$, then:

$$t_x = \frac{2\pi a_x \xi''.A_x}{2\pi r_1 B_1 \xi_1 \sqrt{\mu}\sin\alpha.c}$$

when a_x is the distance from the center of gravity of the surface A_x to the center of the wheel. After reducing:

$$t_x = A_x.\frac{a_x}{r_1}\cdot\frac{\xi''}{\xi_1}\cdot\frac{1}{B_1}\cdot\frac{1}{\sqrt{\mu}\sin\alpha}\cdot\frac{1}{c}\cdot \quad (49).$$

The distance a point of the wheel at the distance x from the center of the wheel moves in the time t_x is:

$$y_x = V_x . t_x$$

when V_x is the velocity of the wheel at this point. This velocity is:

$$V_x = \frac{x}{r_1} V_1$$

By use of this value and equation (4) it is found that:

$$y_x = \frac{A_x}{B_1}\cdot\frac{x}{r_1}\cdot\frac{a_x}{r_1}\cdot\frac{\xi''}{\xi_1}(\cot\alpha + \cot\beta)\,. \quad (50)$$

If the line that represents the path which a particle of water describes, is known, then is the form of the vanes obtained by assuming several values for x, and from them finding the corresponding values of y_x, which are set from this line along the circumferences of the wheel, which correspond to the values of x. These distances y_x determine the form of the vanes.

In order to obtain the best form of the path in which a particle of water ought to move, when it passes through the wheel, we will consider that the water moves with a constant acceleration in direction opposite from that in which the wheel is going. Then the following equations for a uniform accelerated motion can be used, namely:

$$v = v_0 + at$$

$$S = v_0 t + \frac{at^2}{2}$$

if v_0 is the velocity at the beginning of the time t, v the velocity at the end of the same time t, a is a constant acceleration and S the distance passed through in the time t. If the course of the water, in direction opposite from that in which the wheel is going, is considered relative to the direction ae'—see Fig. 3—in which the water enters the wheel, then is $v_e = o$ in the general equations, and,

$$v = at \quad . \quad . \quad . \quad . \quad . \quad (51).$$

$$S = \frac{at^2}{2} \quad . \quad . \quad . \quad . \quad . \quad (52).$$

For the radius r_2—see Fig. 3—the value for v is

$$E = \frac{\sin(\delta + \varphi)}{\sin\delta} \cdot c_2$$

if the line ae' represents the direction in which the water enters the wheel, δ the angle between this line and the tangent to the circle in the point e', and the line $a\ b\ c\ d\ e\ f$ the path of a particle of water. The value of a in equations (51) and (52) is then:

$$a = \frac{v}{t} = \frac{\sin(\delta + \varphi)}{\sin\delta} \cdot \frac{c_2}{t}$$

The distance which the water has been removed for the radius x is according to equation (52)

$$S_x = \frac{\sin(\delta + \varphi)}{2.\sin\delta} \cdot c_2 \cdot \frac{t_x^2}{t}$$

From equation (49) the value of t is found to be:

$$t = A. \frac{a}{r_1} \cdot \frac{\xi}{\xi_1} \cdot \frac{1}{B_1} \frac{1}{\sqrt{\mu}\sin a} \cdot \frac{1}{c}$$

By use of the values of t and t_x we have:

$$S_x = \frac{\sin(\delta + \varphi)}{2\sin\delta} \frac{A_x^2}{A} \cdot \frac{(\xi'')^2}{\xi.\xi_1} \cdot$$
$$\cdot \frac{a_x^2}{a.r_1} \cdot \frac{1}{B_1} \frac{1}{\sqrt{\mu}\sin a} \cdot \frac{c_2}{c} \quad . \quad . \quad . \quad . \quad (53).$$

From Fig. 3 it is easy to find that:

$$\cos\delta = \frac{r_1}{r_2}\cos a$$

Also after some transformations, by use of this equation is:

$$\frac{\sin(\delta + \varphi)}{\sin\delta} = \sin\varphi.$$
$$\cdot \left(\cot\varphi + \frac{\cot a}{\sqrt{m^2 + \cot^2 a(m^2 - 1)}}\right) \quad . \quad . \quad . \quad (54).$$

From equations (15), (53) and (54) is then found that:

$$S_x = \frac{A_x^2}{2.A} \cdot \frac{(\xi'')^2}{\xi.\xi_2} \cdot \frac{a_x^2}{a.r_2} \cdot \frac{1}{B_2} \cdot$$
$$\cdot \left(\cot\varphi + \frac{\cot a}{\sqrt{m^2 + \cot^2 a(m^2 - 1)}}\right) \quad . \quad . \quad . \quad (55).$$

If $x = r_2$ then is:

$$S_e = \frac{A}{2} \cdot \frac{\xi}{\xi_2} \cdot \frac{a}{r_2} \cdot \frac{1}{B_2} \cdot$$
$$\cdot \left(\cot\varphi + \frac{\cot a}{\sqrt{m^2 + \cot^2 a(m^2 - 1)}}\right) \quad . \quad . \quad . \quad (55).'$$

By use of equation (55) the line that represents the path of a particle of water in its passage through the wheel may easily be constructed, and from this is then obtained, by use of equation (50), the form of the vanes. By use of such a form is obtained an almost uniform pressure of the water against the vanes, in the direction of the motion of the wheel.

If it should be desirable to construct the vanes in an easier way, then equation (55) may be avoided, and only equation (50) used. Then ought the path of the water between the radii r_1 and r_2 to be constructed as a parabola, and in such a way as will now be shown. In order to construct this line, the point e—see Fig. 3—is assumed, and through it a line fg is drawn, so that the angle between this line and the tangent to the periphery at the point e of the wheel is φ, and a parabola is drawn as Fig. 6 indicates, so that the lines ae' and fg are tangents at the points a and e. Assume that this parabola represents the path of a particle of water. It ought to be observed, that when the water has left the circumference, which corresponds to the radius r_2, the path ef ought to be a straight line, because at this part of the wheel the water has to perform no work. When now the path $abcdef$ of a particle of water is known, the equation (50) is used to obtain the form of the vanes. In order to find the form of the vanes, the form of the cross section of the wheel must be known, so that the value A_x can be obtained; but the form of the cross-section of the wheel depends upon the path of the water through the wheel if a good flow of the water is desired. For that reason the line which represents the path of a particle of water must at first be approximately assumed, in order by its use to construct the cross section of the wheel. This cross section is easily obtained if it is assumed that the water will have to spread gradually.

When the cross section of the wheel is found, and from it the curve, that represents the path of a particle of water, is obtained from equation (55), and it is found of different shape from the line approximately designed, then no change of the cross section of the wheel should be made because the approximate form and the calculated one can not be very different. When wheels are to be designed the use of equation (55) can be avoided as before stated. In order to obtain the cross section of the wheel assume the line *abcdef*—see Fig, 3—to be be known. Divide this line in any number of parts and set their rectified lengths in the same order on the line *a'f'*—see Fig. 5. The line *aa* represents the width of the wheel at the inlet, and *ee* the width at the outlet. Divide the line *at*, which is drawn through the point *a*, parallel to the line *a'f'*, in the point *m*, so that the line *am* is equal to the line *mt*, and draw a straight line through the points *e* and *m*. Draw in such way as Fig. 6 indicates, a parabola through the points *a* and *e*, so that the lines *am* and *mf* become tangents to this curve. The surface *aaff* represents thus the form a sheet of water ought to have in flowing through the wheel. The cross section of the wheel is now easily obtained in the manner shown by figures 3, 4 and 5, and the construction of it will easily be understood from these figures. The surface $a_1a_1e_1e_1$—see Fig. 4—is then the surface which is denoted by the letter A, and the surface $a_1a_1d_1d_1$ is that denoted by A_x.

For wheels where the radius r_1 is greater than the radius r_2, the values of B_x that correspond to the values of x, when the values of x are less than the radius r_2, ought to be found from:

$$\frac{B_x}{B_2}=\frac{\xi_2}{\xi_x}\cdot\frac{r_2}{x}\cdot\frac{1}{\sqrt{1+\cot^2\varphi\left\{1-\left(\frac{r_2}{x}\right)^2\right\}}}\quad(56).$$

which is easily obtained, if it is assumed that the velocity of the water has a constant value and that the path of the water is a straight line. How to find this equation will now be shown. In the same way as equation (15) is obtained, it is found that:

$$1=\frac{c_2}{c_2}=\frac{\xi_2}{\xi_x}\cdot\frac{B_2}{B_x}\cdot\frac{\sin\varphi}{\sin\varphi_x}\cdot\frac{r_2}{x}$$

Also is easily found from Fig. 8 that:

$$x\cos\varphi_x=r_2\cos\varphi$$

and then:

$$\sin\varphi_x=\sqrt{1-\left(\frac{r_2}{x}\right)^2\cdot\cos^2\varphi}$$

By use of these equations is the equation (56) obtained.

This equation must be used for all inward flow turbines, because in these wheels the water will increase in its velocity when it leaves the wheel, which gives a loss of efficiency.

The guides in the guide case ought to be made so that the water enters the wheel through the angle α to the periphery at the inlet of the wheel, and the forms of the guides ought thus to be made as involute curves. Such a curve is obtained if a circle with a radius of the value $r_1\sin\alpha$ is drawn, with the center of the wheel as a center, and the involute curve to this circle is constructed, which curve gives the form of the vanes.

The value of ξ at the guide case must be the same as ξ_1 and never less.

GENERAL THEORY FOR TURBINE WHEELS.

The notations used in this theory are the same as in the theory for radial flow turbines, notwithstanding the change of notations in Fig. 9. A turbine of this

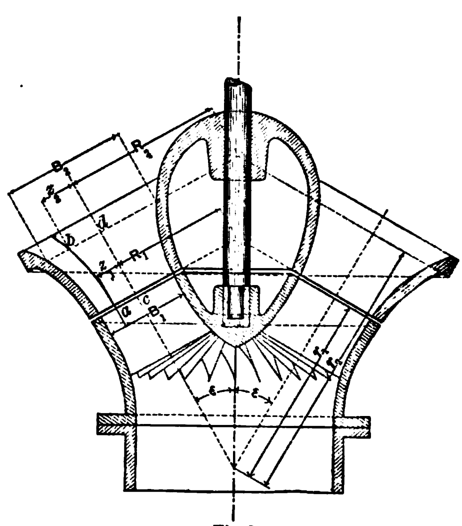


Fig.9

form is a parallel flow turbine when the angle $\varepsilon=o$, and an outward or inward radial flow turbine when $\varepsilon=90°$. If r_2 is greater than r_1 or less than r_1, then they will be respectively outward and inward flow turbines.

Assume that Fig. 9 represents a turbine in general, and that the sheet of water that enters the wheel at a discharges at b, and that:

$$z_2 = \frac{B_2}{B_1} z_1 \quad . \quad . \quad . \quad . \quad . \quad (57).$$

If the thickness of this sheet of water at a is equal to Δz then is its thickness at b $\frac{B_2}{B_1}\Delta z$. In order to calculate these wheels in the easiest way we should assume that:

The normal velocity of the water when it enters the wheel is a constant, and thus the value of $\sqrt{\mu}$ sin a is also a constant. For one and the same turbine the value of μ must be a constant and thus also the angle a *a constant* value, independent of the value of the distances to the center line of the wheel.

If it is assumed that the line cd is a center line of the cross section of the wheel, then this line divides the distances B_1 and B_2 in two equal parts.

Assume that the value of z_1 is negative if the distance from the point a to the center line of the wheel is less than the distance from the point c to the center line of the wheel. The value of z_2 is positive or negative in the same way.

The proportion between the velocities of the wheel at the points b and a will be denoted by m_z. Then is:

$$m_z = \frac{R_2 + z_2}{R_1 + z_1} \quad . \quad . \quad . \quad . \quad (58).$$

From equations (57) and (58):

$$m_z = \frac{1}{1 + \frac{z_1}{R_1}} \left(\frac{R_2}{R_1} + \frac{B_2}{B_1} \cdot \frac{z_1}{R_1} \right) \quad . \quad . \quad . \quad . \quad . \quad (59).$$

If $\varepsilon = 90°$ then the values R_1 and R_2 become infinite and the value of m_z is:

$$m_z = \frac{R_2}{R_1} = \frac{r_2}{r_1} = m$$

which is the value of m for radial flow turbines.

For the sheet of water, that flows through the wheel along the line ab, the equations for radial turbines can be used, if in those equations the value m_z is used instead of m.

When a wheel is to be calculated we at first assume $z_1 = 0$ and then calculate the value of m_z from the equation (59), then by use of the previously given equations for radial turbines the values of β, γ and φ are found. For the sheet of water that enters the wheel at a, the values of β_z γ_z and φ_z are to be found. For the point a the value of m_z is obtained from equation (59). For this point the velocity of the wheel is then:

$$V_z = \frac{R_1 + z_1}{R_1} \cdot V_1$$

$$= \frac{R_1 + z_1}{R_1} \cdot \sqrt{\mu}.\sin a(\cot a + \cot \beta).c$$

when β is the value of β which is obtained for $z = o$.

Also according to equation (4) is:

$$V_z = \sqrt{\mu}\sin a(\cot a + \cot \beta_z)$$

Thus is obtained that:

$$\cot \beta_z = \frac{R_1 + z_1}{R_1}(\cot a + \cot \beta) - \cot a \; . \; (60).$$

By use of the previously given equations (28) and (29), or (41) and (42), the values of cot γ_z and cot φ_z are also to be found. By assuming various values for z_1, both positive and negative, the form of every part of the wheel can be found. In practice it is enough to assume only three values of z_1, namely,

$$+\frac{B_1}{2},\; o \text{ and } -\frac{B_1}{2}$$

In order to find the relative efficiency of the wheel we must find the values η_z and take their mean. It is easy to find that for the sheet of water, which enters the wheel in the point a, the value η_z is:

$$\eta_z = 1 - \frac{\mu \sin^2 a}{m_z^2} \left(\frac{\xi_1}{\xi_2} \right)^2 \cdot \left(\frac{B_1}{B_2} \right)^2 (1 + \cot^2 \varphi_z)$$

$$\left\{ 1 + \left(\frac{z_1}{r_2 - r_1} \right)^2 \left(\frac{B_2}{B_1} - 1 \right)^2 \frac{1}{1 + \cot^2 a} \right\} . \; (61).$$

or approximately:

$$\eta_z = 1 - \frac{\mu \sin^2 a}{m_z^2} \left(\frac{\xi_1}{\xi_2} \right)^2 \cdot \left(\frac{B_1}{B_2} \right)^2 (1 + \cot^2 \varphi_z)$$

The efficiency of the wheel is then:

$$\eta = \frac{\Sigma (R_1 + z_1).\eta_z}{\Sigma (R_1 + z_1)} \quad . \quad . \quad . \quad . \quad . \quad (62).$$

If as before asserted only three values $+\frac{B_1}{2}$, o and $-\frac{B_1}{2}$ of z_1 are assumed, then it is found that:

$$\eta = \frac{\left(R_1 + \frac{B_1}{2} \right).\eta_+ + R_1.\eta_o + \left(R_1 - \frac{B_1}{2} \right)\eta_-}{3.R_1} \quad . \quad . \quad . \quad . \quad (63).$$

when η_+, η_0 and η_- are the values of η_z obtained for the values

$$+\frac{B_1}{2},\ o \text{ and } -\frac{B_1}{2} \text{ of } z_1.$$

The dimensions of a turbine wheel are to be found if the power required, the head of water and the least value of η required are known. If N is the number of horse power required, then the volume of water that must be used per second is:

$$Q=\frac{75}{1000}\cdot\frac{N}{H}\cdot\frac{1}{\eta}\quad . . . \quad (64).$$

when meter and kilogram are used, and

$$Q=\frac{550}{62.4}\cdot\frac{N}{H}\cdot\frac{1}{\eta}\quad . . . \quad (64)'$$

when feet and pounds are used.

The value of c, that corresponds to the whole head of water is:

$$c=\sqrt{2g.H}\quad . . . . \quad (13).$$

If the value of $\sqrt{\mu}\sin\alpha$ is assumed to be known, then:

$$2\pi.\frac{r_1.R_1}{\sqrt{r_1^2+R_1^2}}.\xi_1.B_1=\frac{Q}{\sqrt{\mu}\sin\alpha.c}\quad . \quad (65).$$

which equation gives the relation between the values of r_1, R_1 and B_1 and thus the dimensions at the inlet of the wheel.

For a radial flow turbine is then:

$$2\pi\xi_1.B_1r_1=\frac{Q}{\sqrt{\mu}\sin\alpha.c}\quad . . . \quad (66).$$

and for a parallel flow turbine:

$$2\pi\xi_1B_1.R_1=\frac{Q}{\sqrt{\mu}\sin\alpha.c}\quad . . . \quad (67).$$

One more equation may be used to find the dimensions of the wheel, if the value of cot φ is very small:

$$m.\frac{B_2}{B_1}=\frac{\sqrt{\mu}\sin\alpha}{\sqrt{1-\eta}}\quad . . . \quad (68).$$

which value is obtained by approximating equation (24).

In order to make it better understood how to use the equations, the calculations for a wheel, of the form indicated by Fig. 9, will now be given. Calculations of turbines of other forms are to be made in the same way.

Assume that a turbine shall give 160 horse power in order to perform useful work and to overcome the friction in the journals, by an effective head of water of 5 meters, that is to say that the virtually head of the water is diminished by heads that correspond to the losses of efficiency occurred by the friction of the water in the penstock and the wheel, irregular motions and changes of the direction of the water in its flow. The efficiency is to be not less than 80 per cent. of the natural power.

Assume that the water discharges under the lowest surface of the water in the tail race.

Assume that: $\varepsilon=45°$, $\sqrt{\mu}\sin\alpha=\frac{1}{2}$, $\xi_1=0.95$ $\xi_2=90$ and $\frac{B_2}{B_1}=1.2$. From the equation (68) is obtained: $m=0.93$. Assume $m=1.25$, which gives better efficiency.

The volume of water per second is according to equation (64): $Q=3$ cubic meters. The value of c is from equation (13) found to be: $c=9.91$ meters. Since the angle ε is 45°: $R_2=r_2$ and $R_1=r_1$. From the equation (65) is obtained:

$R_1.B_1=0.1435$, and thus if $B_1=\frac{R_1}{2}$: $R_1=0{,}536$ meter. Then is $R_1=536^m/_m$, $R_2=670^m/_m$, $B_1=268^m/_m$, $B_2=322^m/_m$. Assume α of such a value that: $\cot\alpha=1{,}5$. From equation (10) is: $\mu=0{,}81$.

If $z=o$ then from equation (59) $m_z=1.25$ which is the value as before assumed. Assume $\cot\varphi=o$, then is found from equation (48): $\cot\gamma=2.37$. From equation (40): $\cot\beta=-0.167$. From equation (30) $\frac{V_1}{c}=1.33$. The value of n is:

$$n=\frac{30}{\pi}\cdot\frac{V_1}{r_1}\sqrt{1+\cot^2\varepsilon}$$

$$n=\frac{30}{\pi}\cdot\frac{c}{r_1}\sqrt{\mu}.\sin\alpha(\cot\alpha+\cot\beta).\sqrt{1+\cot^2\varepsilon}\quad . . . . \quad (69).$$

because the distance of the point c to the center line of the wheel is: $r_1.\sin\varepsilon$.

Then is: $n=333$. From equation (61) $\eta_0=0.876$.

If $z=+134^m/_m$ then from equation (59): $m_z=1.24$. From equation (60): $\cot\beta_z=0.167$. From equation (41): $\cot\varphi=-0.341$. From equation (42): $\cot\gamma=2{,}57$. From equation (61): $\eta_+ 0.858$.

If $z=-134^m/_m$ then from equation (59): $m_z=1.27$. From equation (60): $\cot\beta_z=-0.50$. From equation (41):

cotφ=0.568. From equation (42): cotγ =2.40. From equation (61): η_{-}=0.839. From equation (63) the efficiency of the wheel is found to be η=0.859.

In order to review the relations between different turbines, the following tables were made for turbines constructed in such a way, that the discharge is under the lowest surface of the water in the tail race. For turbines, where the discharge is in the air, there are about the same relations between different turbines. For these wheels the value of γ is some greater.

Tables for Radial Flow Turbines.

	$\sqrt{\mu}\sin\alpha$.	m.	cot α.	μ.	$\frac{B_2}{B_1}$.	cot φ.	cot γ.	cot β.	$\frac{V_1}{c}$.	η.
1*)	½	1.20	0.00	0.25	0.94	0.78	4.00	2.39	1.20	0.688
2	"	"	"	"	1.00	0.94	"	2.12	1.06	0.672
3*)*)	"	"	"	"	1.18	2.00	"	1.18	0.59	0.370
4	"	1.00	"	"	1.00	0.59	"	3.41	1.71	0.664
5*)	"	"	"	"	1.12	0.78	"	2.88	1.44	0.678
6*)*)	"	"	"	"	1.41	2.00	"	1.41	0.71	0.339
7	"	0.85	"	"	1.00	0.40	"	4.98	2.49	0.598
8*)	"	"	"	"	1.32	0.77	"	3.39	1.69	0.669
9*)*)	"	"	"	"	1.65	2.00	"	1.68	0.84	0.275
10*)	⅓	"	"	0.11	0.88	0.78	"	5.07	1.69	0.679
11	"	"	"	"	1.00	1.14	"	3.97	1.32	0.648
12*)*)	"	"	"	"	1.11	2.00	"	2.50	0.83	0.374
13	½	1.2	0.50	0.31	1.00	0.00	5.76	3.50	2.00	0.827
14	½	1.20	0.50	0.31	1.50	0.00	8.64	3.50	2.00	0.918
15	"	"	"	"	1 00	0.27	4.00	2.09	1.29	0.813
16	"	"	"	"	0.69	0.00	4.00	3.50	2.00	0.638
17	"	"	1.00	0.50	1.00	"	2.88	1.00	1.00	0.827
18	"	"	"	"	1.50	"	4.32	1.00	1.00	0.920
19	"	"	1.73	1.00	1.00	"	1.66	−0.58	0.58	0.827
20	"	"	"	"	1.50	"	2.49	−0.58	0.58	0.923
21	"	1.00	0.50	0.31	1.00	"	4.00	3.50	2.00	0.750
22	"	"	"	"	1.50	"	6.00	3.50	2.00	0.882
23	"	"	1.00	0.50	1.00	"	2.00	1.00	1.00	0 750
24	"	"	"	"	1.50	"	3.00	1.00	1.00	0.885
25	"	"	1.73	1.00	1.00	"	1.16	−0.58	0.58	0.750
26	"	"	"	"	1.50	"	1.73	−0.58	0.58	0.887
27	"	0.85	0.50	0.31	1.00	"	2.89	3.50	2.00	0.654
28	"	"	"	"	1.50	"	4.33	3.50	2.00	0.836
29	"	"	1.00	0.50	1.00	"	1.45	1.00	1.00	0.654
30	"	"	"	"	1.50	"	2 17	1.00	1.00	0.840
31	"	"	1.73	1.00	1.00	"	0.83	−0.58	0.58	0.654
32	"	"	"	"	1.50	"	1.25	−0.58	0.58	0.843
33	⅓	"	0.50	0.14	1.00	"	6.50	8.50	3.00	0.846
34	"	"	"	"	1.50	"	9.75	8.50	3.00	0.927
35	"	"	1.00	0.22	1.00	"	3.25	3.50	1.50	0.846
36	"	"	"	"	1.50	"	4.88	3.50	1.50	0.929
37	"	"	2.83	1.00	1.00	"	1.15	−1.24	0.53	0 846
38	"	"	"	"	1.50	"	1.72	−1.24	0.53	0.930
39	½	1.10	1.73	1.00	1.00	"	1.40	−0.58	0.58	0.793
40	"	"	"	"	1.50	"	2.10	−0.58	0.58	0.906
41	1.00	2.00	0.00	1.00	1.00	0.52	4 40	0.97	0.97	0.684
42*)	"	"	"	"	1.20	0.80	"	0.75	0.75	0.715
43	"	"	"	"	1.50	1.58	"	0.47	0.47	0 613
44*)	½	"	"	0.25	0.60	0.80	"	1.50	0.75	0.714
45*)*)	"	"	"	"	0.78	2.20	"	0.71	0.35	0.385

For the wheels 1—40 is assumed that $\frac{r_2-r_1}{B_1}=1$ and for 41—45 $\frac{r_2-r_1}{B_1}=3$. The equations marked with *) are calculated by use of equation (46) and those marked with *) *) are calculated under assuming of the maximum value for cotφ. For all wheels is assumed that $\xi_1=\xi_2$.

Tables for Parallel Flow Turbines.

	z_1	$\sqrt{\mu}\sin a$	cot a	μ.	$\frac{B_2}{B_1}$	cot φ.	cot γ.	cot β.	$\frac{V_1}{c}$	η_z	η.
1.	$+\frac{B_1}{2}$	½	0.00	0.25	1.00	0.44	5.00	4.55		0.702	
	0	"	"	"	"	0.59	4.00	3.41	1.71	0.664	0.654
	$-\frac{B_1}{2}$	"	"	"	"	0.88	3.16	2.28		0.577	
2.	$+\frac{B_1}{2}$	½	0.50	0.50	1.00	−0.13	5.21	4.83		0.746	
	0	"	"	"	"	0.00	4.00	3.50	2.0	0.750	0.745
	$-\frac{B_1}{2}$	"	"	"	"	0.25	2.92	2.17		0.737	
3.	$+\frac{B_1}{2}$	½	1.73	1.00	1.00	−0.43	1.11	−0.19		0.703	
	0	"	"	"	"	0.00	1.16	−0.58	0.58	0.750	0.688
	$-\frac{B_1}{2}$	"	"	"	"	0.86	1.63	−0.96		0.566	

For these three turbines it is assumed that $B_1 = \frac{3}{8} R_1$. For all wheels it is assumed that $\xi_1 = \xi_2$.

Fig. 3 represents the turbine No. 20, and Fig. 8 the turbine No. 42. The turbine Fig. 8, is constructed under the unfavorable assumptions of $\sqrt{\mu}\sin a = 1''$ and $a = 90°$; but by using the value of m as high as 2, this wheel will give an efficiency of 71 per cent. of the natural power.

The turbine theory above considered is believed to be totally unlike all theories hitherto used. By assuming the value of the normal velocity of the water at the inlet of the wheel, as the first requisite for further calculations, the theory is made very simple, and an exact theory could be made for turbines in general. By using the values cotangents instead of the angles a theory is obtained, which does not require the use of trigonometrical tables, as there is no need of knowing the values of the angles. To determine the angles by use of the cotangents is very easy. Turbines in general have never had, to the knowledge of the writer, any theory. Also the way to find the form of the vanes is unlike other methods. To my knowledge there has never been any exact theory for turbines in use, and therefore it is hoped that the theory now published will be found of help to those who wish to make good turbines.

SNOW CLEARING IN TURIN.

By SIGNORI PECCO and PRINETTI.

From "L'Ingegneria Civile," for Abstracts of the Institution of Civil Engineers.

Turin and its suburbs are divided into three districts for this purpose, of which two are urban, comprising all the paved roads, and one district is suburban, comprising all communal roads. Each district is subdivided into sections varying in number from five to eight. The work is done by petty contractors, who find labor, horses and carts, and is paid for at a price per centimeter of snow fallen. The city provides tools. The street sweepers are also employed at intersection of main streets and other important points, and to sprinkle sawdust, &c., on the roads.

The snow is first thrown up in heaps, and then thrown into the sewers, rivers and canals, or stacked in special places. The sewers are flushed from a canal in the upper part of the city.

Several mechanical methods of melting the snow have been investigated with the following results: Garneri's Tube Calorifer consists of a galvanized iron pipe, with a fire at one end and a fan for drawing hot air through it at the other. The snow is heaped round the tube. The cost amounted to 2⅛d. per cubic yard (without reckoning the cost of the apparatus), as against 1d. per cubic yard for clearing away in the usual manner. The pyro-hydro-melting plough was a machine proposed by Garneri for melting the snow *in situ*, but did not seem worth trying. Nawckins and Mullaly's (New York) snow melter consists of a boiler from which a mixture of steam with the gaseous products of combustion issues in one or more jets upon the snow. The cost for fuel alone would be ¾d. per cubic yard of snow melted, to which must be added interest and sinking fund for machine costing £1,280. Bouvet's system resembles the tube calorifer, but the tube is pierced with small holes from which steam issues. Melting by salt.—It has been found in Paris that 0.36 lbs. of salt is required to melt a frozen stratum 1 yard square and 1½ to 2 inches thick. The price of salt in Turin being 2.4d. per lb., the cost would amount to 16d. per cubic yard. Wells as receptacles for snow.—It not being thought advisable to try any of the above systems, it was proposed that a well should be dug to receive the snow from one contract. The subsoil of the city is gravel, through which a large body of water passes. A well, 16 feet 6 inches diameter, 42 feet 6 inches deep, amply sufficed in 1880–81 to receive the snow from an area of 13,150 square yards. This system is rapid and economical where the cost of cartage exceeds ¾d. per cubic yard.

The area from which the snow was removed in 1880–81 was 2,800,000 square yards; the total depth of snow was 1.41 foot. There were one hundred and twenty-one contractors. The number of men sometimes amounts to four thousand (besides the regular sweepers), and five hundred carts. On January 19th, 1881, three thousand six hundred and eighty-four men and four hundred and seventy-five one-horse carts were employed to clear away a depth of 0.46 foot of snow. The average cost for clearing and carting a cubic yard is 0.93d. in districts 1 and 2. In district 3, where it is only heaped up, it is 0.4d. In addition to these amounts paid by the contractors there is the cost of providing and maintaining tools, and the charge for canals, &c.; these items, with superintendence, add from 20 to 25 per cent. to the cost. The total cost per inch depth of snow is £274.

The tramway companies have to bear their share of the cost, and pay for clearing a width of 9 feet 10 inches for single and 19 feet 8 inches for double line. For a length of 17½ miles of tramway the cost is £12 11s. per inch depth of snow.

The question of letting the work to one or two large contractors has been considered by the authorities, but the present arrangement is thought to be the best. In the event of dispute with a large contractor the snow would be left lying in the street, while the men now employed can be dismissed at a moment's notice and readily replaced, and they are satisfied with a lower rate of pay than a contractor would demand, who provided his own tools, and was required to have large gangs of men always available, with the possibility of having no work for them throughout the winter. The superintending staff consists of twenty engineers and assistants, who take great interest in the work, which involves much responsibility in cases of emergency. In the busiest parts of the city the snow is heaped up by 9 A.M., when the depth does not exceed 6 inches, and is cleared away within twenty-four hours. In all the inhabited parts the heaping up is done in one day and the removal in two days more. A copy of the regulations for the contractors is added, and also a table showing the surface cleared, the total depth of snow and the total cost for each year from 1859–50 to 1880–81. From this it appears that the area has increased from 1,273,000 square yards to 2,803,000 square yards; that the depth has varied from 1¼ inch to 36½ inches; and the cost from £240 to £7,040. There is also a list of tools, carts, &c., kept in store for this service.

A DYNAMO-ELECTRIC machine has been designed by Dr. Paget Higgs in which the armature is almost completely encircled by tubular ring magnets.

THE INSTITUTION OF CIVIL ENGINEERS.

INAUGURAL ADDRESS OF THE PRESIDENT, SIR W. G. ARMSTRONG, C.B., F.R.S.

From "The Engineer."

He observed that it had been the practice of his predecessors in the chair, to select topics for their address that had reference to branches of engineering which operated to increase the productiveness of human industry, and there were many who would contend that all engineering efforts ought to center upon that object. It might be fully admitted that the general amelioration of the material condition of the world was the noblest object of engineering science; and if men and nations ceased to be bellicose and rapacious, such would naturally be the direction which all engineering practice would take; but this was a world of contention, where no individual state could insure its independence, and carry on its industrial occupations in safety, without protecting itself against the possible aggression of its neighbors. Thus it was that the science of the engineer was invoked for the purposes of war as well as for those of peace; and it was probable that the engineering element would, in future, enter more and more largely into the operations of war, until the issue would be chiefly dependent upon the superiority of mechanical resource, displayed by one or other of the contending parties. There was no country in the world less disposed to be aggressive than our own, but there was none so likely to incite the greed of an assailant, or so vulnerable in relation to its commerce. War indemnities had degenerated into mere exactions proportioned to the wealth of the vanquished; and England, being the richest of nations, offered the highest premium for successful attack. As to commerce, England had more than one-half of the ocean carrying trade of the whole world in her hands, and her ships, swarming over every sea and conveying merchandise of enormous value, would, in the event of war, invite the depredations of hostile decrusiers. We had seen in recent years what ravages a single-armed ship could inflict upon a mercantile navy incomparably smaller than our own, and, in our case, it was not only property, but indispensable food that was at stake. The ever-increasing population of Great Britain had already far outgrown its internal means of support, while the increasing cheapness of imported food so discouraged native agriculture that we might expect our future dependence upon foreign supply to increase even more rapidly than our population. This was not the occasion to discuss either moral questions affecting war, or political questions concerning free trade. We had the stern fact before us that national defence was in our case peculiarly a necessity, and the question how it could best be effected, from an engineer's point of view, was a legitimate subject for this address.

England must always be chiefly dependent for security upon her naval power, but we could not hope that she would ever again be so dominant at sea as before the introduction of steam navigation. So long as naval superiority depended upon seamanship and an unlimited supply of sailors, no nation or combination of nations could compete with us; but as soon as it became established that fighting ships could be maneuvered with more certainty and precision by the power of steam than by the power of wind, a revolution began which had gradually made naval warfare a matter of engineering rather than of seamanship. The introduction of rifled ordnance and percussion shells was the second step in this revolution, and had the effect of condemning as useless the whole fleet of wooden ships with which all our victories had been won, and which were the pride of the nation. Then commenced that contest between guns and armor which had gone on to this day, and had not yet been decided. Nor would it, in all probability, ever be decided, seeing what an *ignis fatuus* finality was. The most recent stage of this revolution was that marked by the introduction of torpedoes, against which our ponderous ironclads were no more secure than ships of thinnest iron. These constantly-changing phases of attack and defence had placed our naval authorities under extreme difficulty in deciding upon questions of ships and armament. To stand still was impossible, while to act upon uncertain data was sure to lead to mistake. The necessary consequence had been that types and patterns of ships had been continually changing, and vessels, costing vast sums of money, had become nearly obsolete almost as soon as made. We could not wonder that, so long as invulnerability was conceived to be attainable, great sacrifice should be made for its accomplishment; but with our present knowledge, which it would be unfair to apply to a criticism of the past, we might feel assured that invulnerability was a chimera. Not only did we see that armor was unavailing against torpedo attack and ramming, but we were justified in concluding that every attempt to increase resistance to projectiles would be quickly followed by a coresponding increase in the power of artillery. Our early ironclads, like the Warrior, were plated all over with armor 4½ in. thick—a thickness which could now be pierced with field pieces. To resist the most powerful guns now afloat, armor of at least 2 ft. in thickness was required; and in order to reconcile the constantly-increasing thickness with the weight which the ship was capable of carrying, it had been necessary to restrict the area of armored surface to ever narrowing limits, leaving a large portion of the ship without protection. In those magnificent and tremendous vessels which the Italians were now building, the armor would be withdrawn from every part except the battery, where guns of 100 tons would be placed, and where the armor would be confined to a narrow belt of great thickness. Everything of importance that projectiles could destroy would be kept below water level, and, so far as artillery fire was concerned, the ships would be secured against sinking by means of an under-water deck and ample division into compartments. Armor therefore seemed gradually contracting to the vanishing point; but, until it actually disappeared, it was probable that no better application of it could be made than had been decided upon by the acute and enterprising naval authorities of Italy for the great ships they were now constructing.

The dread of the terrible effects of the fragments of shells bursting amidst a crowded crew, and the apprehension that the smoke from the explosion, when it occurred between decks, would paralyze the service of the guns, had conduced more than anything else to the adoption of armor. Methods of avoiding or lessening these dangers, otherwise than by the use of armor, had been little considered; yet the alarming aspect of the case was greatly altered, when we reflected that, by the application of mechanical power, to do what had hitherto been done by a multitude of hands, the exposure of a crowded crew could be avoided, and also that the guns might all be mounted on an open deck, where the smoke from shells would speedily clear away.

As to the comparative liability of an ironclad and an unarmored ship to be sunk by projectiles, there was much less difference between them than was generally supposed; because the unarmored ship, though freely penetrable, might be so constructed that the entrance of water by perforation could not extensively flood the ship, unless it took place at a great number of critical places. Indeed, by introducing an under-water deck, with divisional spaces, and by the partial application of cork, as in the Inflexible, for displacing influent water, and thereby preserving stability, and also by a proper distribution of coal for the same purpose, an unarmored ship might be rendered almost incapable of being sunk; and it was rather surprising that so little attention had been directed to the attainment of that object.

It was not too much to say that, for the cost of one ironclad we could have three unarmored ships of far higher speed, and carrying collectively three armaments, each equal to that of the armored vessel. It might be asked, Which would be the better investment? If it were imagined that the three were matched in combat against the one, it would be perceived that, in addition to their numerical superiority, the former would possess many advantages. Being smaller they would be more difficult to hit. Being swifter they could choose their positions and be free to attack or retreat at pleasure. Being more nimble in turning they would be better adapted both for ramming and for evading the ram of their adversary. Finally, the conditions of superior speed and agility would favor their use of torpedoes and submarine projectiles; although it was a question whether, for the sake of a much needed simplification, it would not be better to confine that species of attack to separate vessels specially constructed for that one particular purpose. Even if the utmost advantage she could possess were conceded to the ironclad, viz., that of being impenetrable by the guns of her opponents, she could not prevail in a contest of three against one, unless by the use of securely-protected artillery she could keep her assailants at bay, and gradually destroy them by her fire if they persisted in their attack. Such might be the issue if the allied vessels had nothing but guns to oppose to guns; but they would, naturally, under such circumstances, place their men below, out of the reach of projectiles, and then attack with their rams or torpedoes. With the crews in safety, it was scarcely possible that unarmored vessels, with under-water decks and all their machinery beneath, should suffer any disabling injury by being pierced in a few places by either shot or shell. But take the much more probable alternative of the armored vessel being penetrable by the guns which would be used against her. In that case her enemies might elect to make the contest one of artillery. On their part, armor-piercing projectiles would be used, which, on penetrating the thick sides of the ironclad, would carry inboard a mass of broken material far larger in quantity than the fragments of the shells with which they would be assailed, and quite as destructive in effect. The ironclad would have to sustain the converging fire of three ships, each carrying the same armament as her own, and her swift and nimble adversaries would steam round and round her, directing their fire on the most vulnerable points, and ever ready to seize a favorable moment to dash in and finish the contest by ramming. In either case, therefore, the ironclad would be over-matched by a combination of unarmored vessels representing the same pecuniary value. Without entering into technical questions concerning fleet fighting, it seemed reasonable to believe that the result would be the same if the number engaged on each side were proportionately multiplied. Inferiority of speed and of number would still give the choice of position, and secure the advantage of converging fire, besides with the greater power of division and of concentration must always belong to the more numerous fleet. But if ironclads were not needed for the purpose of opposing ironclads it was difficult to see for what purpose they were wanted at all. For every other kind of service a numerous fleet of smaller and swifter vessels, unencumbered with armour, would clearly be preferable. To protect our commerce, to guard our extensive seaboard against invading flotillas, to lend naval assistance to our colonies in case of need, and generally to maintain our supremacy at sea, we required a far more numerous navy than we possessed or could afford to possess unless we vastly reduced our expenditure on individual ships, and to do this we must dispense with armor. It might, perhaps, be rash entirely to abandon armor, so long as other nations continued to use it, because nothing but the experince of an actual war would remove all question as to its possible utility; but considering the indisputable value of a numerous fleet of swift and powerfully-armed ships, built with a view of obtaining the maximum amount of unarmored defence, and considering that such vessels, unlike armor clads, could never grow much out of date, it did seem to be expedient that the chief expenditure of this country should be upon ships of that description. Lightness should be the special aim in the construcction of such vessels. Steel plates should be used for the hulls, and guns and engines should be of the least possible weight consistent with the necessary power. Every ton of weight saved would enable higher speed to be attained, and there was probably no quality in a flying ship which would so much develop in importance as that of swiftness. Messrs. Thornycroft has led the way in showing what extraordinary speed could be realized in diminutive vessels, by reducing to the utmost the weight of every part of the structure and its contents; and although we could not expect to attain proportionate speed by the same method in ocean-going ships of war, yet there could be no question that we might have far swifter ships than at present if lightness were made the principal object, instead of the prevalent practice of loading ships with cumbrous armor, in the vain hope of rendering them invulnerable. Light unarmored ships, designed by Mr. George Rendel, had lately been built in this country for foreign powers, which, with a displacement of only 1,300 tons, had attained a speed of 16 knots an hour. They carried coal for steaming 4,000 miles, and had already actually steamed 3,500 miles without replenishing. They were each armed with two 10 in. new-type guns, which had nearly an all-round fire, and were capable of piercing 18 in. of iron armor; and with four 40 pounders on the broadsides. It was a very serious question what could be done in the event of a number of such vessels as these being let loose upon our commerce. At present there was not a single ship in the British navy carrying an armament competent to engage them, that could overtake them in pursuit, or evade their attack when prudence dictated a retreat. Confidence was often expressed in our mercantile marine being capable of furnishing, on an emergency, a supply of vessels fit to be converted into cruisers; but where were there to be found amongst trading or passenger steamers, vessels possessing a speed of 16 knots, with engines and boilers below water level, and having an under-water deck to save them from sinking when penetrated by projectiles at or below the water line. From his own experience he knew how difficult it was to adapt mercantile vessels to the purposes of war, and how unsatisfactory they were when the best had been made of them. It was alarming to think how unprepared we were to repress the ravages which even a small number of swift marauding vessels, properly constructed and armed for their purpose, could inflict upon the enormous property we had at all times afloat, and how little we could hope to clear the sea of such destructive enemies, by cruisers improvised out of ready-made steamers destitute of all the conditions necessary to render them efficient for such a service. It must ever be borne in mind that it was not merely the loss of property and interruption of trade that we had to fear, but also the interception of food supplies; and that the more our population increased and our agriculture declined, the more terribly effective for reducing us to submission, would be the stoppage of those supplies.

The President then adverted to harbor defence. He pointed out that many of our ironclad forts had already outlived the stage of artillery progress for which they were adapted. He expressed his opinion as to the best method of rendering large guns effective in shore batteries. He dwelt upon the value of gunboats, considered as floating gun carriages, and used in combination with torpedo craft and submarine mines; all of which, he suggested, might be committed to the management of trained naval and engineer volunteers resident on the spot.

He said it would be a grand development of the volunteer movement, of which this country was so justly proud, if it were thus to be extended to harbor defence; and he was informed that, so far as the use of submerged torpedoes was concerned, a project of intrusting their employment to a corps of volunteer engineers was already under consideration. The superior education and intelligence of the class from which our volunteers were mostly supplied would especially fit them for the discharge of duties involving skill and discretion, such as would be required in the handling of electrical apparatus, and we might be sure that, wherever dash was needed in the use of torpedo boats, there would be no lack of that quality amongst volunteers in the hour of trial.

On the subject of artillery, he described the progress of gun manufacture since the introduction of rifled ordnance, prior to which a gun was simply a tube of cast iron or bronze closed at one end. He also discussed the question, what, under the present conditions and prospects of steel manufacture, should be our practice as to the use of that material for artillery purposes. He was then led to speak of a system of construction which had not passed through the experimental stage, but which, from the results it had already given, promised to attain a wide application. He referred to that system in which the coils surrounding the central tube consisted of steel wire, or ribbons of steel, wound spirally upon the tube. To those who objected to welded coil tubes on the ground of supposed deficiency of longitudinal strength, this mode of construction must appear especially faulty, inasmuch as lateral adhesion, instead of being, as contended, merely deficient, was altogether absent; while to those who advocated the present coil system, this variety must commend itself as affording the greatest possible amount of circumferential strength that could be realized from the material employed. Steel in the form of wire or drawn ribbon, possessed far greater tenacity, and also greater toughness, than in any other condition, and in applying it to guns there was perfect command of the tension with which each layer was laid on. He then alluded to the labor of those who had worked in this direction, and referred to a 6-in. breech-loading gun of this construction made at Elswick, and tried in the beginning of 1880. He stated that the charges used with it were large beyond precedent, and the energies developed proportionately high. Being satisfied with the results obtained with this gun, a second one of larger dimensions had been commenced, and was now finished. Its caliber was 26 centimeters or about 10¼ in. Its length was 29 calibres, and its weight was 21 tons. In the previous gun he depended for end strength upon the thickness of barrel only; but in the new one, layers of longitudinal ribbons were interposed between the coils, in the proportion of one longitudinal layer to four circular layers. The longitudinals were secured to the trunnion ring at one end and to a breech ring at the other, and were in themselves calculated as sufficient to resist the end strain on the breech, independently of the strength afforded by the tube. The whole was encased in hoops shrunk upon the exterior of the coil, for the treble purpose of protection from injury, of preventing slipping in the event of the failure of an external strand, and of adding to the strength of the gun. This gun had already been tried, and had given results which, in relation to its weight, were unexampled except by its 6-in. predecessor. Various attempts had also been made abroad to reduce this system to practice, and it was understood that the French were at present engaged in making experimental guns upon the same general principle. With regard to the ribbon form of section, he preferred it to a square section of equal area, as being more favorable for bending over a cylinder, but any rectangular form was better than round wire, on account of the flat bedding surfaces it afforded.

He then discussed the subject of breech loading and muzzle loading, and the various forms of rifling. He also described the many changes that had been found necessary in the form and manufacture of powder for heavy ordnance, and the difficulties which still remained to be overcome.

As to the mounting of guns in forts and ships, he remarked that the difficulties of the problem were much greater than was commonly supposed. It was certain that machinery could no longer be dispensed with for working the guns, and that engine power must be used to economize labor and avoid exposure of the men. In the days of cast iron smooth bores, the heaviest naval gun weighed 95 cwt., and it was deemed impracticable to exceed that limit in a ship. At the present time the heaviest naval gun in the British service was 80 tons, and guns of 100 tons were carried in Italian ships. Instead of projectiles weighing as a maximum 94 lbs., and charges of 16 lbs., we had now to handle projectiles of 1,500 lbs. and charges of 450 lbs.; and to keep pace with foreign navies those limits of weight must be greatly exceeded. Even if it were possible to deal with guns and ammunition of such weights by manual labor, the multitude of men required for the purpose would be greater than could find standing room at the guns. Up to a certain point hand power might be so aided by machinery as to enable larger guns to be worked by men than was formerly deemed possible; but the mechanism required to render hand labor available was quite as liable to be disabled by an enemy's fire as that which would be applied in connection with engine power. There was therefore no reason in this respect for employing a numerous gun crew in preference to inanimate power. Automatic methods of running out the gun, by which the gun was lifted in recoiling by slides or radius bars and recovered its position by gravitation, might in many cases be advantageously used to save labor, but in a ship the varying inclination of the deck interfered with uniformity of action. The upward motion of the gun also involved the objection of a higher port, and it added greatly to the downward shock, which became very severe on the deck where the guns were large and were fired at considerable elevation with such heavy charges as were now usual. Steam power, acting through the medium of hydraulic pressure, was already largely applied in recent ships for effecting all the operations of working the guns, and where such power was used there was nothing to gain by automatic action for returning the gun into firing position. In considering these various mechanical arrangements now applicable to naval warfare, we perceived the growth of the engineering element in our ships of war, and the importance of mechanical, as well as nautical, acquirements on the part of the officers, as also, in a less degree, on that of the men. Breech-loading guns, carriages fitted with all modern appliances, shot and powder lifts, mechanical rammers and torpedo apparatus, all combined with steam or hydraulic machinery, or with both, constituted mechanisms requiring to be supervised by officers qualified as engineers, and to be handled by men trained in the use of machinery.

Before drawing to a conclusion he would advert to a subject of grave national importance. Our Navy was at present armed with guns which could not be expected to contend successfully with the best modern guns that could be used against them. Happily, most of the older ships of foreign powers were in the same predicament; but all their now vessels, and some of their older ones, were being armed with artillery which, weight for weight, was far superior in power to that of our Navy. Our service guns had simply been overtaken in that rapid progress of artillery which had been going on for the last eight or ten years; and it might be doubted whether any partial remodeling during that period would have averted the present need of re-armament; while it would certainly have involved great sacrifice and confusion of ammunition and stores. But a new departure could not longer be delayed. An irresistible demand had arisen for breech-loading guns, and it was imperative to combine, with the introduction of that system, such other modifications of construction as would realize the increase of power which we now know to be attainable.

It might, however, be asked, What better prospects of finality there was now than we had ten years ago? As to absolute finality, it would probably never be reached, but the country might take some comfort in the reflection that every stage of progress narrowed the field for further development. There was already no substantial room for improvement in the accuracy of guns; and as to power, we were nearly approaching the limit at which severity of recoil and extravagant length of gun would prohibit further advance. We might go on building larger guns almost without limit, though he doubted the policy of so doing, but mere increase of size did not revolutionize system. There seemed, therefore, to be more hope of permanency now than at any former period; but whether this were so or not, we could not, with danger, remain passive.

What, then, should our Government do in regard to the great work of re-arming the fleet? He took it for granted that all new ships would be armed with the best guns that could now be made, and that the more important of the older vessels would speedily receive the same advantage; but beyond this, so long as experience of novelties was deficient, it was a case of cautious procedure. In the mean time, no expense should be spared in judicious experiments, seeing that the expense of experiments was trifling in comparison with that of mistakes. Above all, the Government should pursue such a course as would bring into full play the abundant engineering resources of this highly mechanical country, for increasing the efficacy of our National defences.

The vicar of Dudley contemplates the use of the electric light in the parish church.

ON THE INSUFFICIENCY OF RESERVOIRS FOR DIMINISHING THE DANGER OF FLOODS.

By M. GROS.

From "Annales des Ponts et Chaussees," for Abstracts of Institution of Civil Engineers.

The utility of reservoirs in diminishing damage from floods was taken into consideration in France, after the inundations of 1856. Investigations were made in the valleys of the Seine, the Rhone, the Loire, the Garonne, and other important rivers, and resulted in the decision not to carry out the numerous reservoirs which had been proposed, owing to the uncertainty and doubtful efficacy of their action on floods.

Similar investigations were made on these rivers after the inundations of 1875. These latter observations showed, in the case of the Garonne, that a reservoir capacity of 720,000,000 cubic yards would be required to protect Toulouse from a similar flood, and two or three times larger to protect Agen and the rest of the basin. The Saint-Ferréol reservoir, supplying the Canal Du Midi, which has been cited as a specimen of the reservoirs that should be constructed, has only a capacity of under 8,000,000 cubic yards, so that a very great number of similar reservoirs would be required for protecting effectually the basin of the Garonne. The capacity, however, of the reservoirs which would be of value in reducing the height of floods, and could be constructed in the upper valley of the Garonne, would amount to only one-sixth of that required for protecting Toulouse. The investigations led to similar conclusions in the case of the lower Garonne, and of the other principal river basins of France.

The distribution of rain and advantages of situation would oblige the reservoirs to be placed as much as possible in the hilly portion of the basins, where, however, owing to the declivity, the reservoirs would be smaller, and would be liable to be rapidly filled up with detritus. It might also sometimes happen that a flood would be produced by a heavy rainfall in the lower part of a river valley, as was the case in the great flood of the Garonne in 1875, and then the reservoirs in the hills would be useless.

The action, moreover, of reservoirs on the river further down, with an increasing discharge, becomes rapidly less. Thus a lowering of the Rhone at Lyons of 3¼ feet, by means of reservoirs above, would amount to only 1⅛ foot below the confluence of the Saône, and to only 8 inches below the confluence of the Isere at Valence. In like manner a retention of 130,000,000 cubic yards on the Garonne at Toulouse would only act like a retention of 65,000,000 at the mouth of the Tarn, of only 52,000,000 at Agen, and of only 23,000,000 at Tonneins, and its effect would become insignificant at Langon. This shows how large the reservoirs in the upper valleys would have to be made to produce an adequate effect in the lower portions of the rivers. Reservoirs on tributaries, by retarding a flood, would modify the flow in the main river in a variety of ways, which could hardly be determined beforehand, and might be injurious by causing a coincidence of floods.

Often continuous floods are produced by the coming down of several high floods at short intervals apart. Thus the inundation of the valley of the Garonne in 1856 was caused by five successive floods, keeping the river in flood for more than two months. Under such circumstances the reservoirs would be filled by the first flood, and would not be available for lowering the subsequent floods. The reservoir embankments might be endangered by the flow of water over them, and a failure of an embankment might entail more disasters than a very high flood.

It has been proposed that flood reservoirs should be also utilized for supplying canals, for irrigation and water power, thus serving a double purpose. Flood reservoirs, however, to be useful against floods, must be kept empty throughout the whole season when floods may occur. Storage reservoirs have small outlets, and a flood discharge would have to flow over the embankment or over a wide overfall weir. Such an arrangement might be adopted in a rocky valley, and where the discharge of a river is small; whilst the erection of high embankments across the lower valleys, where the discharge is large and the ground liable to be eroded by the fall of the water, would be dangerous.

The system of reservoirs for providing against floods must accordingly be entirely abandoned, not only on account of the excessive expense and difficulty of obtaining adequate capacity, but also because a carefully designed system of reservoirs along a river valley, which might provide against a flood occurring under definite conditions, would be totally inadequate to cope with all the various combinations of distribution of rainfall and floods of tributaries, by which floods are produced in the main river.

THE LAW OF GEOTHERMIC PROGRESSION.

By P. VAN DIJK.

From "Revue Universelle des Mines." Translated for Institution of Civil Engineers.

Under this general title, employed to signify the relation which the subterranean temperature of the earth bears to the depth below its surface, the author investigates first the theoretical transmission of the central heat outwards through the earth's solid crust, from its highly heated core in a state of ignition or fusion; and secondly the inverse transmission of external cold inwards. The expression "geothermic scale" (German *geothermische Tiefenstufe*, and French *échelon géothermique*) being taken to denote, at any distance below the earth's surface, the additional depth which at that point corresponds with a rise of 1° in temperature, he shows that the geothermic scale will increase, according to the first mode of investigation, with increasing distance outwards from the hot core; and, according to the second mode, with increasing depth below the surface.

The outward transmission of central heat is amenable to theoretical investigation alone, as regards that portion of its vast range which is by far the largest, and in which its effects would be by far the most noticeable; and it is only at the remotest extremity of its range, within the comparatively insignificant depths accessible from the earth's surface, that deductions from this theory can be confronted with observed facts. The results of the equations arrived at by the author for the outward transmision of central heat, representing curves of hyperbolic character, would be a practically uniform geothermic scale throughout the greatest depth accessible; while, even if the observed temperature continued appreciably constant down to that depth from the surface, instead of increasing with the depth, such a condition would not preclude the existence of a fused or fiery core. Moreover, if the earth were entirely solid to its very center, the temperature at that point would then have to be infinitely high.

The inward penetration of external cold, on the other hand, admits at once of investigation by theoretical and by practical methods; and it is within the most effective portion of its range, namely, down to the depths accessible from the earth's surface, that deductions arrived at from this theory can be verified or corrected by observations made in sinkings, which have been executed to various depths in different parts of the world. The available observations employed for this purpose, by the author, are collected by him into the accompanying table. The data obtained from the bore holes in the island of Java are the results of observations made by M. Ermeling, engineer officer, by M. Hooze, mining engineer, and by the author himself, who is mining engineer-in-chief in the Dutch East Indies. The data from the Sperenberg bore hole have previously been quoted; others are taken from Naumann.

A glance at the concluding column of this table suffices to show that the geothermic scale increases with the depth in every observation here noted. Former representations of a uniform rise in temperature proportional to the increase in depth, giving a constant scale which was roughly stated at 30 meters depth per degree centigrade, or 55 feet per degree Fahr., are thus confuted at the outset, not only in regard to any individual locality, but also in comparing widely diverse regions; for while that value of the geothermic scale would be nearly reached at Yakutsk at 400 feet depth, it is not attained till, 1,400 feet at Nausalzwerk, and 2,300 feet in Java. From this observed increase of the geothermic scale in higher latitudes, where the mean annual temperature of the locality is lower, it may be inferred that the earth's crust is probably thicker in polar regions, and thinner near the equator.

Plotting in the form of diagrams the principal data in the table, the author tries how closely the curves so obtained can be fitted by hyperbolic, logarithmic, and parabolic curves; and thereby arrives at presumptive evidence in corroboration or otherwise of certain of the observed data thus employed. From his previous equations for the outward transmission of central heat, he deduces a hyperbola as representing also the inverse penetration of external cold into a solidified sphere, formerly hot and now cooling from its surface inwards. But the idea of the earth's solidity throughout to its very center, already seen to be irreconcileable with the theory of the outward transmission of central heat, is equally incompatible with the observed inward penetration of cold, inasmuch as the geothermic progression deduced from the observations in Java would assign to the earth's solid center a temperature not exceeding the boiling point of water.

Law of Geothermic Progression.—For the complete curve of geothermic progression therefore the author combines these two inverse modes of investigation; and by this means he finds the relation between the depth x below the earth's surface, and the corresponding temperature y, to be exactly represented by the equation

$$y=\frac{TR^2+CRx}{(R-x)^2}-\frac{H(T-t)}{H+x},$$

where R is the earth's radius, and C, H, T, t, are constants for any indi-

TABLE OF OBSERVED SUBTERRANEAN TEMPERATURES, AND CORRESPONDING INCREASE OF GEOTHERMIC SCALE.

Bore hole or well.	Depths below surface. Meters.	Feet.	Temperatures noted. Centigrade.	Fahr.	Geothermic scale. Meters per deg. Cent.	Feet per deg. Fahr.
Bore holes at Batavia, and at Grissée, in Java. Latitude 6° S.	0	0	26.0	78.8		
					12.5	22.7
	70	230	31.6	88.9		
					15.6	28.4
	140	459	36.1	97.0		
					18.0	32.6
	165	541	37.5	99.5		
					20.0	36.4
	416	1,364	48.0	118.4		
					31.2	56 8
	728	2.388	58.0	136.4		
Artesian bore hole at Grenelle, Paris. Latitude 49° N.	0	0	10.7	51.3		
					25.9	47.1
	298	977	22.2	72.0		
					45.3	82.4
	547	1,794	27.7	81.9		
Bore hole at Neusalzwerk, Westphalia.	0	0	10.0	50.0		
					19.5	35.5
	189	620	19.7	67.5		
					29.7	54.1
	418	1,371	27.5	81.5		
					45.7	83.2
	697	2,286	33.6	92 5		
Rore hole at Rüdersdorf, near Berlin. Latitude 52° N.	0	0	9.1	48.4		
					15.5	28.2
	124	407	17.1	62.8		
					25.3	46.0
	286	938	23.5	74.3		
Bore hole at Sperenberg, near Berlin Latitude 52° N.	0	0	9.0	48.2		
					17.4	31.7
	220	722	21.6	70.9		
					26.0	47.3
	345	1,132	26.4	80.0		
					33.4	60.8
	659	2,162	35.8	96.4		
					37 8	68.8
	1,064	3,490	46.5	115.7		
Well at Yakutsk, Siberia. Latitude 62° N.	0	0	−10.3	13.5		
					7.2	13.0
	15	50	− 8.2	17.2		
					10.9	19.8
	30	100	− 6.8	19 8		
					15.2	27.7
	45	150	− 5.8	21.6		
					19.1	34.8
	60	200	− 5.0	23.0		
					21.6	39.0
	75	250	− 4.3	24.3		
					28.8	52.4
	116	382	− 2.9	26.8		

vidual bore hole, t being the observed surface temperature in that particular locality, and T the temperature communicated to the surface at that place from the earth's hot core. The equation represents indeed simply the difference between the hyperbolic curve $y_1 = \frac{TR^2 + CRx}{(R-x)^2}$, already arrived at by the author for the outward transmission of heat through the earth's crust from its hot core, and the true hyperbola $y_2 = \frac{H(T-t)}{H+x}$, representing the inward penetration of cold from the earth's surface; and H is the height above the earth's surface of the temperature asymptote to this hyperbola of cold penetration. The three constants, C, H, T, are determined by assigning any three pairs of observed values to x and y; and the three temperature observations employed for the purpose should be taken as wide apart in depth as possible. The tedious determination of these constants is much simplified, without materially impairing the correctness of the results, by noting that the extreme depth included in the foregoing table does not exceed 3,500 feet; and that as far as 1,760 feet depth at least, or one-third of a mile, the fraction $\frac{x}{R} = \frac{1}{12,000}$ may be neglected in comparison with unity. Then the above equation for the law of geothermic progression assumes the simpler form

$$y = T + \frac{C}{R}x - \frac{H(T-t)}{H+x}.$$

The complete curve of geothermic progression presents a point of inflection, at which the geothermic scale will attain its maximum value. Considering by how very large an amount the temperature of the earth's fused or igneous core, even if assumed no higher than 3,000° C. or 5,000° F., exceeds the surface temperature, in comparison with the difference between the surface temperature and the absolute cold of the universe (−276° C. or −465° F.), it follows that the point of inflection in the geothermic curve must occur very much nearer to the earth's external surface than to the interior surface of its crust; and the author calculates that the maximum value of the geothermic scale, occurring at the point of inflection, will be but very slightly greater than its mean value for the entire thickness of the earth's crust. The depth at which the mean value will be attained of the geothermic scale for the whole thickness of the earth's crust in the thinnest portions is probably not more than 3,000 meters (10,000 feet). In Java, where the geothermic scale starts from the surface at about 12 meters per 1° C. or 22 feet per 1° F., its mean value is calculated at 54 meters per 1° C., and its maximum at 57 meters, or 100 feet and 105 feet respectively per 1° F. At Yakutsk, with 7 meters per 1° C. or 13 feet per 1° F. at starting, the mean value would be 155 meters per 1° C. or 280 feet per 1° F.

Other general conclusions arrived at by the author are, that the observed regular increase in the geothermic scale proves the earth to be in process of gradual cooling from a primeval uniformly heated state; but that, as the loss of heat from its surface, though incessant, is infinitely small in comparison with its store of central heat, a large portion of its interior mass must still remain at a very high temperature. Assuming 3,000° C. or 5,000° F. as the temperature of its fused or igneous core, the thickness of the crust in its thinnest or equatorial portion is probably not more than one-fortieth of the earth's radius, and in the thickest or polar portions three or four times as great, or even more. The thickness in any given latitude will also be greater beneath a deep ocean, owing to the mean temperature of the sea being lower than that of the land; thus the most sudden differences of thickness will occur under a latitude where, with a high mean temperature at the surface, the alternations of land and deep sea are the most frequent; and this view is in keeping with the mainly volcanic character of the islands in the equatorial archipelago. Local disturbances, such as volcanic eruptions, earthquakes, and geysers, as well as gradual upheaval or subsidence of tracts of land, cannot be more simply explained than by the reaction which the earth's solidified crust, of considerable thickness, and possessing low conductivity for heat, exerts upon its fused or igneous core.

COMPRESSED AIR UPON TRAMWAYS.

By W. D. SCOTT MONCRIEFF.

From "Nature."

Few persons unconnected with the practical working of the companies are aware of the great amount of time, labor, and money which have been devoted to the substitution of mechanical for horse power upon tramways both in this country and abroad. The principal incentive to this exertion has been the large margin of saving which has presented itself in the light of a premium to inventors and capitalists. Motives of humanity toward the horses have also had considerable influence, especially with Parliament, and have contributed in no small degree to the legislative sanctions which have been obtained not only by particular companies, but by the tramway interest in general. In no case, however, that the writer is aware of, have the tramway companies themselves made any material contributions towards the solution of the problems involved. When the story of the subject comes to be written it will be found full of arguments in favor of the principle that the monopoly granted to inventors by the patent laws is nothing more than a clumsy method of spurring them to exertion, and of providing a remuneration for success which never covers the aggregate losses of failure by which the whole community have been indirectly benefited.

The fact of the horse-tramway companies having refused to assist inventors with money is fully accounted for and rendered excusable, not only because they have no funds placed at their disposal by their articles of association for such a purpose, but also because the investment would have been far too speculative to have been sanctioned by the shareholders. Where the companies appear to the writer to have been at fault is that while the margin of saving as between a successful invention and horse traction is admitted to be enormous, because the invention could hardly be said to be successful unless the margin was a large one, they have never admitted either individually or collectively that some substantial share of the saving should be the reward of the successful inventor. The writer has no hesitation in saying that if the leading companies had put the issue clearly before the inventive capacity of the engineering profession in the shape of an offer of say 30 per cent. of the actual saving in the shape of royalty to the inventor that the problem would have been solved at least six years ago. The far-stretching results of such a revolution, even within the comparatively confined area of the tramway interest, would be incalculable. Not to speak of the emancipation of the horses, the employment of capital in channels so consistent with the spirit of the age and the genius of the country, as the manufacture of machinery, would have economic results affecting the welfare of whole classes of the community, and the impetus given to the intramural locomotion of our large cities would go far to overcome the pressure of difficulties affecting the housing of the poor, which contribute more to the unrest of the people and the propagation of socialistic ideas than the wealthier classes are aware of. The policy of the tramway companies, however, in appears to have assumed the character of a fixed determination to give nothing in return for the advantages which would accrue to them from the adoption of a successful mechanical substitute for horses. So long as they maintain this attitude the problem is likely to remain unsolved. Licenses of inventors have followed their example, and at least one case is known to the writer in which a gross breach of agreement has debarred the adoption of an invention which is notoriously efficient. Time no doubt will expose the guilty parties, and their names, instead of being honorably associated with the advance and improvement of mechanical science, will be handed down to posterity with the contempt which they deserve.

A description and illustration have already been given in these pages of a system of tramway traction by means of electricity, and this is no doubt safe in the hands of the distinguished specialists who have taken it up. In the paper which the writer read recently before the Institute of Mechanical Engineers at Manchester, and which has already been reproduced in the engineering journals (see *Engineering*, vol. xxxii., No. 829), a sufficient explanation of his views was given upon the merits of the use of steam locomotives upon tramways compared with compressed air. The objections to steam were based principally upon its failure to comply with the necessary conditions of street traction, in the matter of freedom from smell and dirt, and also on account of the excessive cost incurred by the maintenance of small high-pressure boilers and machinery. No such objections can be urged against the use of compressed air, as compared with electricity, because in both cases there is nothing to give trouble or annoyance from the residual products. In the one case the air escapes in its original purity to the atmosphere from whence it was derived, and in the other a still more subtle transference of force occurs, in which the conversion of one form of energy into another is all that takes place in order to effect the object aimed at. The overhead wire, in the Siemens system, which is the stage at which the invention at present stands, is a disadvantage as compared with a self-moving car in which no such obstruction is necessary to its working. Overlooking this objection to the rival system which may possibly be overcome by the use of accumulation of electric force in the vehicle itself, the point upon which the success of both must ultimately turn is that of their comparative economy. At present there are no figures to hand that can satisfactorily decide the question. In both cases a stationary engine is a necessary adjunct in order to supply a source of energy, and the future of both hinges (1) upon the comparative cost of the plant, and(2) upon the percentage of useful work which can be obtained from the use of compressed air and electricity respectively. These questions can only be answered by the trial of both upon a commercial scale, but it may safely be said in the meantime that there is nothing to lead to the conclusion that compressed air will appear to a disadvantage either as regards the necessary outlay in machinery or in the percentage of useful work to be obtained from it, as compared with electricity.

The conditions which effect the useful effort exerted by a steam engine through the intervening medium of a permanent elastic fluid such as air, employed as the ultimate vehicle of the original force upon a piece of mechanism, are first the loss from friction of the compressing apparatus; second, the loss represented by the difference between the temperature of the air as freshly compressed without radiation, and the temperature of the air as used in the second engine. These may be spoken of as the primary losses of energy. The secondary losses are: first, the friction of the secondary engine; and secondly, the losses arising from its inability to utilize the whole of the force contained in the air as compressed and cooled. Now the theoretical losses arising from these various causes are all easily determined, with the exception of that arising from the defects of the secondary engine, and this, which amounts to more than all the rest put together, not only varies in each separate case, but may be fairly looked upon as being capable of indefinite reduction by discoveries and improvements in the apparatus itself.

With regard to the fixed losses; the one which occurs from the loss of heat, due to compression and subsequent cooling, is one that can be restored under circumstances of peculiar economy, as there is perhaps no condition in the whole range of physics which lends itself so readily to the economical conversion of heat into work as raising the temperature of an elastic fluid under compression and making use of it at a corresponding pressure. It must be remembered, however, that what we are dealing with in practice is not so much the saving of every heat unit of the original supply for the purpose of producing a theoretical result and a beautiful experiment, as bringing the gross expense of the fuel used in the original steam boiler to a point that leaves a sufficient margin as compared with horse traction, and in such a manner as not to interfere with the convenience of passengers. The writer has already in actual practice brought this gross sum per mile for fuel to ½d., when coal is used costing 10s. a ton, a common-enough price in districts where tramways are in use. Now in attempting to reduce the cost of fuel to a smaller fraction of a penny than ½d. per mile run, it occurred to him that the effort should be made first in the direction in which the greatest loss occurred. This is certainly to be found in the defects of the secondary engine if an ordinary reciprocating steam engine is employed, and an explanation of the writer's work in adapting it to the use of compressed air will be found in the paper already referred to. The result of his experience has gone to show that it is hopeless to obtain an economical result from reciprocating engines as at present arranged for the use of steam, without some special appliances such as he has adopted for making use of the ever-varying rates of expansion necessary in the case of a self-moving car. By reason of the additional apparatus required for re-heating the air resulting in grave inconvenience, and effecting an economy of perhaps not more than one-fifteenth of a penny per mile in fuel, he has not as yet included a heating appliance in the arrangements, and strong arguments would require to be brought to bear upon him before he determined upon doing so. The importance of introducing a heating apparatus would turn more upon what might be gained by adding to the capacity of a self moving air-car with the view of making it capable of overtaking a particular journey for which the cold air was insufficient, than upon a mere question of economy, but even in this case he believes it would be more convenient and economical to add to the quantity and pressure of the air in the receivers than to make use of a separate heating appliance to obtain the same result.

Compressed air as a locomotive power is represented by three different systems, known respectively by the names of their inventors. All of them are more or less protected by patents, and taking the dates of the patent specifications as the standard of priority, the writer's stands first upon the list. The other two are known as Mékarski's and Beaumont's. The writer is the only one of the three who has made public in this country, otherwise than by patent specifications, the scientific work which he has overtaken, and the exact principles upon which his engines have been constructed. Before Col. Beaumont took out a patent at all he had driven in the writer's car and examined it, but as he has departed from his original specification the writer has had no means of comparing the efficiency of the engines, as recently constructed, with his own. On the occasion of his reading the paper at Manchester, already referred to, a letter from Col. Beaumont was read by M. Bergeron, in which it was stated that the engine now running at Stratford used 10 cubic feet of air per mile, at 1,000 lbs. pressure per square inch, or 666 cubic feet at atmospheric pressure. This efficiency is more than 50 per cent. less than the writer's car, without allowing for the loss of power arising from the use of a heating apparatus, and the higher initial pressure of 66 as compared with 26 atmospheres to begin with. If this statement is correct the writer's views with regard to a moderate pressure and avoiding the use of a heating apparatus, except when absolutely necessary, are fully confirmed.

A heating apparatus, and reducing the initial pressure of the air by means of what is known as a reducing valve, are essential elements of the Mékarski system, but the engine would require to be considerably modified before it could comply with the requirements of the Board of Trade in this country.

The experiments which are now being made by the Beaumont Compressed Air Engine Company, at Stratford, with a separate engine, hauling an ordinary passenger car behind it, are likely to bring the question prominently before the notice of tramway companies, and the hopeful remarks made before the last meeting of the British Association, by Sir Frederick Bramwell, with regard to the use of compressed air, must have contributed towards the same result. The experience of the writer who has been longer at work on the subject than either of the representatives of the systems referred to is, however, so much opposed to their proposals, that he does not feel himself to be an altogether unbiased critic of their proceedings. It is sincerely to be hoped, for the sake of suffering horseflesh, and in order to promote the expansion of intramural locomotion throughout the country, that a fair trial may soon be given to the rival systems, including electricity. This, however, is but a remote contingency if tramway companies continue to adhere to the principle, or rather no principle, that they have to get everything, and the men who add to their dividends nothing, for their pains. The writer's car, which can be seen at work by any one interested, is entirely self-contained, and offers absolutely no obstructions to the convenience of passengers, and it carries forty of them a distance of more than seven miles, with a low and safe pressure of air in the receivers, and without replenishing the supply. The distance it would travel with the pressure used in Col. Beaumont's engine is over twenty miles with one charge of air. The weight complete, including the fittings for passengers, is less than that of any compressed-air tramway engine which the writer knows of, hauling a tramway car behind it.

ALEXANDER LYMAN HOLLEY.

By ROSSITER W. RAYMOND,
Editor of "Engineering and Mining Journal."

In the paralysis that follows the shock of a great personal bereavement, it is not wonderful, though I find it at this moment most lamentable, that I cannot write of the life and character of him who has departed, with the calmness and fullnesss which the subject deserves. If one might weep or cry out in print, feeling at least might find some fit expression, though the mourner would be but a poor substitute for the biographer. But now, alas! I can do justice neither to his virtues nor to my own grief.

It is perhaps fortunate that a part of the work which I cannot to-day find heart or strength to perform, I have done already, under happier auspices. In May, 1879, after the presentation to Mr. Holley at Pittsburg, of a handsome testimonial from the leading Bessemer manufacturers and other friends, I published in these columns, to supplement the report of that event, an account of his career, which I here reproduce. It was carefully prepared as to dates and leading facts; and it has furnished the material for nearly all the notices which have appeared in the newspapers since his death, though in some cases, by careless condensation, that material has been sadly distorted.

Alexander Lyman Holley was born in 1832 at Salisbury, Conn., (where the Institute of Mining Engineers enjoyed, at the Amenia meeting in 1877, the charming hospitality of his parents, Governor and Mrs. Holley). Before his eighteenth year he learned the machinist's trade, and subsequently graduated in 1853, from the scientific course of Brown University, having preferred this training to the classical course at Yale, for which he had been prepared. We cannot help thinking that the classical beginning has had more to do with his success in life than he would probably suspect. To some such influence should be ascribed the general culture and the literary skill which have made his technical knowledge doubly effective on the minds of men.

After graduation, he was employed in a large locomotive works at Providence, and for about a year drove one of the locomotives of the concern on the Stonington Railroad. The following passage from his eloquent address at the Washington meeting of the Institute, on "The Inadequate Union of Engineering Science and Art" (Transactions, iv. 194), shows how powerfully he could feel and express the poetry as well as the practice of that position:

"The thoughtful locomotive-driver is clothed upon, not with the mere machinery of a larger organism, but with all the attributes, except volition, of a power superior to his own. Every faculty is stimulated, and every sense exalted. An unusual sound amid the roaring exhaust and the clattering wheels tells him instantly the place and degree of danger, as would a pain in his own flesh. The consciousness of a certain jarring of the foot-plate, a chattering of a valve-stem, a halt in the exhaust, a peculiar smell of burning, a sudden pounding of the piston, an ominous wheeze of the blast, a hissing of a water-guage—warning him respectively of a broken spring-hanger, a cutting valve, a slipped eccentric, a hot journal, the priming of the boiler, high water, low water, or failing steam—these sensations, as it were, of his outer body, become so intermingled with the sensations of his inner body, that this wheeled and fire-feeding man feels rather than perceives the varying stresses upon his mighty organism."

Either at this time, or during his subsequent connection with locomotive works at Jersey City, occurred a humorous incident which we have heard Mr. Holley relate, and which is perhaps worth repeating. He made a wager with some of his fellows that he could run a locomotive a mile without fire, water, or steam—the locomotive to be taken empty and cold from the shop, and towed by another engine to a point at some distance on the road, where a level stretch of track favored the experiment. Young Holley rode in solitary state on his cold locomotive to the scene of trial, and unsuspected by his escort, so arranged matters that during the trip the motion of the drivers and pistons stored the boiler with compressed air! Of course this gave him, by the time the destined point was reached, an accumulation of power, by means of which he ran out his mile and won his wager.

Before 1855 he had published several technical papers, and had contributed not a little to the columns of Zerah Colburn's *Railway Advocate*. In 1856, he bought the paper, and edited it for about a year, when Colburn resumed his connection with it, Holley retaining half. The hard times of 1857 caused the suspension of the enterprise, and Colburn and Holley went to Europe to study, in the interests of leading American railroad companies, the features of foreign practice. In 1858, their book on *European Railways* was published. Its circulation was large, and its effect was profound. To it may be attributed the rapid improvement in American permanent way and the introduction and perfection of coal-burning locomotives.

Colburn returned to Europe to edit the *Engineer*, and Holley engaged actively in professional writing, chiefly in the editorial columns of the New York *Times*. In 1859, he accompanied Henry J. Raymond to Europe as a *Times* correspondent. In this capacity he made the acquaintance of Brunel and Scott Russell, and thoroughly studied the structure and details of their new marvel the Great Eastern. After a brief interval of editorial work on the *American Railway Review*, he again went to England for the New York *Times* in 1860, to return on the first transatlantic voyage of the Great Eastern. His account of the voyage, and his discussion of the problems of marine engineering and of ocean commerce over the signature "Tubal Cain," attracted much admiration, by their striking combination of picturesque description and technical criticism both thorough and bold. It will be remembered that the New York *Times* editorially prophesied, much to the scorn of several professional papers, that screw steamships would soon drive the side-wheelers, even for passengers, from the North Atlantic. It was Holley who made the prophecy; and we need not say that events fulfilled it. Time vindicated the *Times*.

In 1860 appeared Holley's *Railway Practice*, which immediately took the place of a standard authority. He must have been collecting the materials for this work, during the two preceding years, when he appeared to be wholly occupied with his work as a journalist. His astonishing activity, indeed, eludes our attempts to trace it in detail. We find him superintending experiments in fuel, permanent way, etc., for railway companies, acting as expert in patent cases, and even preparing about a thousand engineering definitions and several hundred illustrations for *Webster's Dictionary* (edition of 1864).

An acquaintance formed through some one of these channels with the late Edwin A. Stevens, at the beginning of the war, led to a temporary connection with the "Stevens Battery," and to the sending of Mr. Holley to England in 1862 to investigate ordnance and armor. The ultimate result of these studies was the book on that subject, published in 1865, which was of itself enough to establish the position of its author in the engineering world. It met with immediate appreciation at home and abroad, was translated and republished in France; and although it is now, of course, behind the times, it remains the standard authority for the state of that branch of the military art at the time of its appearance.

The connection of Mr. Holley with the development of the Bessemer process in the United States is the most important part of his career thus far. It was he who negotiated the purchase of the Bessemer American patents in 1864, built the experimental works at Troy and started them in 1865, built the Harrisburg works in 1867 and superintended them until 1869, rebuilt the Troy works, planned the works at North Chicago and Joliet, the superb Edgar Thomson works at Pittburg, and the Vulcan works at St. Louis. Moreover, it was to his improvements in the mechanical arrangement and details of the Bessemer plant more than to the contributions of any other one man that the astonishing development of the process was due. Mr. Robert W. Hunt, himself one of the earliest and most eminent of our Bessemer engineers, says in his paper on the "History of the Bessemer Manufacture in America" (Trans. Am. Ins. of M. E., v., 201):

"After building the first experimental plant at Troy, Mr. Holley seems to have at once broken loose from the restraints of his foreign experience, and to have been impressed with the capabilities of the new process. The result is, that mainly through his inventions and modifications of the plant we in America are to-day enabled to stand at the head of the world in respect of amount of product."

The example of America has not been without influence abroad. In 1864, the maximum daily product of a pair of five-ton converters in England was 80 tons of steel. We believe it is now perhaps 150 tons per 24 hours there; while in the United States the present average production is 300 tons per 24 hours, and the Edgar Thomson Works have actually surpassed the enormous figure of 9000 tons of steel ingots in one month* (the converters not running on Sundays). We quote again from Mr. Hunt's admirable paper the following summary of Mr. Holley's contributions to this unparalleled record of progress:

"The result of his thought gave us the present accepted type of American Bessemer plant. He did away with the English deep pit, and raised the vessels so as to get working space under them on the ground floor; he substituted top-supported hydraulic cranes for the more expensive counter-weighted English ones, and put three ingot cranes around the pit instead of two, and thereby obtained greater area of power; he changed the location of the vessel

*It has since exceeded 14,000 tons.

as related to the pit and melting-house; he modified the ladle-crane, and worked all the cranes and vessels from a single point; he substituted cupolas for reverberatory furnaces, and last, but by no means least, introduced the intermediate or accumulating ladle, which is placed on scales, and thus insures accuracy of operation by rendering possible the weighing of each charge of melted iron, before pouring it into the converter. These points cover the radical features of his innovations. After building such a plant, he began to meet the difficulties of details in manufacture, among the most serious of which was the short duration of the vessel-bottoms, and the time required to cool off the vessels to a point at which it was possible for workmen to enter and make new bottoms. After many experiments, the result was the Holley vessel-bottom, which, either in its form as patented, or in a modification of it as now used in all American works, has rendered possible, as much as any other one thing, the present immense production."

To say nothing of his incidental literary work in marine engineering and other departments which stamped him as a critic of the first order, any one of these achievements would have entitled him to an honorable professional position. Their union in one man, scarcely arrived at his prime, is almost without parallel.

Mr. Holley was the first editor of VAN NOSTRAND'S ECLECTIC ENGINEERING MAGAZINE; but even he could not long carry that burden in addition to his multifarious professional labors. Since 1870, he has been actively engaged as consulting engineer to numerous Bessemer and other steel works, making frequent journeys to Europe, and issuing to his clients periodical reports of great value. His connection with the open-hearth steel manufacture, and particularly with the introduction of the Pernot furnace and other improvements, which seem likely to effect great progress in that department, is a matter of current history.

As President of the American Institute of Mining engineers in 1875–6, and first Vice-President of the Society of Civil Engineers in 1876, he made his energy and genius felt in both societies, and contributed no little to the growth of that *entente cordiale* which characterizes their relations. The pages of their transactions, as well as those of various cyclopedias, bear witness to his industry, professional enthusiasm, and literary power. His work as a member and advocate of the U. S. Testing Board will be remembered as specially effective.

We are writing, not eulogy, but history. Yet even history may be pardoned, in such a case, for infusing into the words of justice some of the warmth of affection. At a brilliant banquet of the Institute in Pittsburg, the other day, one of the speakers, alluding to the testimonial presented to Mr. Holley the evening before, uttered the feeling of every member of that body, in declaring that the sentiments which had inspired the gift were shared also by those who had not enjoyed the privilege of uniting in such an expression of them. From the verses with which that speech concluded, we quote the final stanzas. Whatever their demerits as poetry, they were offered by the speaker and received by the audience with a feeling that left no doubt of their sincerity and their fitness.

"The Macedonian wept with rage
For other worlds to overrun;
The hero of a nobler age
Has found and claimed them, one by one.

"Realm after realm of fruitful thought
Has hailed our ALEXANER king;
But crowns of conquest all are naught
To those our loyal hearts would bring!

"For weakness at the victor's feet,
Or reason, may reluctant bend;
But love's surrender is complete,
The utter gift of friend to friend.

"O, brother! known in many lands,
And master called in many arts,
Behold, we stretch to you our hands
With nothing in them, save our hearts!"

Who of those who were present will ever forget the presentation to which allusion is made in the above article? Already Holley's health was in such a state as to excite the anxiety of his friends; and there was a terribly pathetic significance in the exquisitely beautiful close of his *extempore* speech:

"Among us all who are working hard in our noble profession, and are keeping the fires of metallurgy aglow, such occasions as this should also kindle a flame of good-fellowship and affection which will burn to the end.

"Burn to the end! Perhaps some of us should think of that, who are burning the candle at both ends. Ah! well, may it so happen to us that when at last this vital spark is oxidized, when this combustible has put on incombustion, when this living fire flutters thin and pale at the lips, some kindly hand may turn us down, not underblown—by all means not overblown—some loving hand may turn us down, and that we may perhaps be cast in a better mould."

A somewhat (but not sufficiently) greater moderation in the intensity of his labors did produce, after this period, a partial restoration of health. But health, with Holley, meant only more power to work. He was like a prodigal who saved merely that he might spend. And so, after a year, it came to pass that he lay at the point of death in London, and a thousand hearts beat with alternate hope and despair, keeping time with the pulses of the ocean cable that brought the tidings of his fluctuating condition. Finally, in August, 1881, the joyful news of his almost miraculous recovery reached this city, in time to be telegraphed to the Lake Superior meeting of the Institute of Mining Engineers; and in the following February he appeared among us, with all his old winning grace and humor, though not with his old vigor. That was another memorable scene, at the Philadelphia banquet in February last, when the large and brilliant assembly welcomed again their well-beloved, and hung upon his words, as with undiminished power he moved them to alternate laughter and tears. We remember, as an instance of consummate art (if it was not rather nature-excelling art), the manner in which, after graphic allusion to his suffering and critical condition abroad, and to the cordial cable telegram sent him from the Lake Superior meeting of his brethren, he paused, and then broke out with thrilling Saxon simplicity: "Oh! how that made me feel!"

A year has passed—for him another year of zeal and activity, in spite of recurring weakness; a year in which, though he struck into no new line of inquiry, he performed some of the best professional work of his life, and perfected what may hereafter be recognized as his greatest invention. We refer to the movable converter shell—an improvement in the Bessemer plant which bids fair to rank with the movable coverter-bottom, and to carry to the utmost limit the productive capacity of the Bessemer process. It was while he lay desperately ill in London that he conceived the idea of this invention, and told a friend who called upon him that he had been "thinking, to pass away the time, and had thought of something which would enable him to die with credit!" This humorous remark expressed a constant characteristic of his mind. His occupation as a consulting engineer, of detecting the weak points in methods and means, and suggesting the best remedies, of hunting up "good things" and recommending them to his clients, was in exact consonance with his disposition. It enabled him to be constantly helping somebody.

We can not now lament that this year of fruitful activity on his part was not rather a year of rest. His impulse was wiser than the prudence of those who would have bid him forbear. For the autopsy performed since his death has shown that the malady under which he had already suffered, and which had puzzled the doctors, was incurable in its nature, and, we may fairly say, not directly traceable to over-work—a tumor, obstructing the gall-duct, and producing many apparent symptoms of liver disease. He was attacked, during a professional journey in Belgium, early in the autumn, with chills and fever, which he ascribed to the malaria of the Low Countries. In spite of the obstinate persistence of this trouble, he managed, before finally breaking down, to finish the work he had laid out in England and Scotland. Then he laid aside for the last time the pen and pencil that had done such splendid service—and the rest of the story is but a monotonous record of patient endurance, heroic courage and cheerfulness, unselfish thought for others, and a calm and absolutely unaffectedly fearless reception of the death message. The immediate cause of his death was *peritonitis*, which suddenly changed what seemed, even to critical eyes, to be but a tedious recovery, into a swift decline. At my last interview with him, only two days before his case became hopeless, and five days before his death, he said (and I thought he was right) that it would be "a long pull," but he should "pull through."

What a Sabbath followed! The quiet chamber where he lay, brave and cheerful, watching and measuring the strength that was ebbing away, as he might have watched and measured the current of a motive power; the storm-beaten ship that steamed up the harbor, bearing those he loved best; the race with death; the arrival of wife and daughters, just too late (God comfort them!)—what insupportable wringing of all hearts, except his, who recognized with calm impartiality when the machinery of life was about to stop, and whose only anxiety was for those who were sailing unawares toward the shadow of death! "Make it as easy for them as you can," he had earnestly said to a faithful friend.

And now the "living fire," fluttering "thin and pale at the lips," has gone out altogether. The heat is over. The bright, true steel has been "cast in a better mould;" and we, who so lately looked upon the brilliant display, now stand in darkness. But the figure fails here. Neither to him nor to us is this the end. For us remains a rich inheritance of knowledge, bequeathed by him, and still more precious treasure of shining example and of tender memory; for him, an earthly fame that might satisfy the highest ambition, and a new life unspeakable, incomprehensible, of powers and opportunities here unknown.

Nay, for me, at least, there still remains a sense of the abiding presence of my dear friend. That flashing spirit, that gentle heart, that hand, so cunning in skill, so cordial in friendship, shall not pass out of my life. Though all the bells of the earth ring funeral peals, I will not say farewell!

REPORTS OF ENGINEERING SOCIETIES.

The American Society of Civil Engineers.—The annual meeting took place on the 18th of January. The first business of the meeting was the election of officers for the ensuing year. The election resulted as follows: President, Ashbel Welch, of Lambertville, N. J.; vice-presidents, James B. Eads, of St. Louis, and William H. Paine, of Brooklyn; secretary and librarian, John Bogart of New York; treasurer, J. J. R. Croes, of New York; directors, Thomas C. Kiefer, of Ottawa, Canada, Colonel Thomas L. Casey, United States Army, Joseph P. Davis, New York, George W. Dresser, New York. Mr. Welch, on taking his seat as president, read an address thanking the members for his election. He said that the society represented every race and clime, and that in the last year proposals for membership had been received from Mexico, Chili, Columbia, England and India. In conclusion he urged the members of the society to "cultivate a wholesome integrity such as preserves the purity of the bench and of the army."

The committee to award the Norman medal reported progress and was continued. The secretary then read the report of the Board of Directors. This report showed the membership of the society to be 605, with 52 Fellows; 62 new members were added in the last year, and 16 members were lost by death, resignation and transfer. The committee on a uniform test for cements, made a report. Sanford Fleming, of Ottawa, chairman of the committee on a uniform system of time, presented the report of his committee, which recommended a general convention of the Government departments and the societies of this country, Canada and Mexico, interested in the subject. The scheme proposed is the establishment of a new system of reckoning time so that it shall be uniform at all points in this country. It is proposed to take a certain meridian, and when it is 12 o'clock there have it called 12 o'clock all over the country. If found necessary or advisable the division of the day into twelve hours is to be done away with and a new division substituted. General Theodore G. Ellis, of Hartford, said that a clock was now being constructed by the Waltham Company which the Signal Service is to set up in Washington, and the clocks of the different stations are to be set to correspond with it, thus avoiding the discrepancies in the computations of time which now occur.

At the afternoon session a committee of directors reported on the subject of tests of American iron, steel and other metals. At the previous meeting a committee had been appointed on this subject with instructions to report to the committee of direction, and its report was transmitted by the board to the meeting. The report recommended that a board be appointed by the Government to superintend the testing of iron, steel and other metals used in construction; that bridges of iron and steel should be included in the tests, and that they should be conducted by a civil board or one composed of officers of the Army and Navy. The report was finally accepted, and a resolution passed directing the committee of direction to take such measures without expense, as it thought expedient to get Congress to establish the Board of Tests and make an appropriation therefor.

A resolution was passed thanking T. F. Rowland for his generous contribution to the building fund of the society, and the Board of Directors was instructed to establish an annual medal of the value of $50, to be known as the Rowland medal, to be offered for excellence in essays read before the society.

Engineers' Club of Philadelphia—Regular meeting of January 21st, 1882.

A paper by Prof. W. S. Chaplin, on the "Relative Tensile Strengths of Long and Short Bars," was presented, on his behalf, by Prof. L. M. Haupt. The object of this paper is to prove that long bars are, on the average, weaker to resist tensile stress than short bars of the same material and cross section, and to show how the reduction in strength may be found when the proper experiments have been made on the short bars.

The Secretary presented a correspondence, in the year 1839, upon the subject of Street Paving, between the Chairman of the Committeee on Public Highways, of the City of Philadelphia and Mr. Thomas U. Walter, Honorary Member of the Club, who was then in Europe, and was requested to furnish information as to the paving of European cities. His letter treats of the ordinary cobble-stone, wooden, granite-block, cobble-stone with flagstone tramways, McAdamized and natural and artificial asphaltum roadways, and is remarkable as exhibiting how much was known upon this subject over forty years ago and how little we have profited by it in Philadelphia.

Mr. D. H. Shedaker submitted an extract, giving account of an exhibition of electric lighting in Trafalgar Square, London, in 1848. The results were so satisfactory that the writer considered that "after a short time we should not be surprised to hear of the total extinction of half the gas companies in the kingdom."

Mr. Charles A. Ashburner explained some difficulties, which have been encountered in the anthracite coal mines of Schuylkill County where the coal beds have been "pinched out" and lost, but which have afterwards been found by driving tunnels at right angles to the strike of the beds and away from the center of the basin. This irregularity of structure seems to have been produced by a folding of the strata at right angles to the strike, by a force exerted in the direction of the basin.

American Society of Civil Engineers, February 15, 1882. The Society met at 8 P. M., President Welch in the chair. A paper by Mr. R. E. McMath of St. Louis, member of the Society; subject, "The Mean Velocity of Streams Flowing in Natural Channels," was read by the Secretary in the absence of the author. With this paper was presented a set of diagrams of curves, deduced from the experiments of J. B. Francis, member A. S. C. E. at Lowell, from the observations of Gen. Theo. G. Ellis, member A. S. C. E., upon the flow of the Connecticut river, from the records of the flow of the Mississippi, made by Gens. Humphreys and Abbott, and also from various other observations of the flow of the Mississippi at Columbus, Ky.; at Vicksburg, Miss.; at Carrolltown, La., and at the passes at the mouth of the Mississippi.

The author of the paper then presented for consideration and discussion the suggestion that to determine a reliable rule for the flow of streams in natural channels, the considerations affecting an artificial channel should be kept entirely distinct; that the definite law of discharge over a weir is usefully applicable at any transverse section above and within the influence of a weir, dam or shoal; that the relation between mean and maximum velocity cannot be used in streams of irregular section; that head is pressure but not in all cases full of surface; that in natural streams the bars or shoals are substituted for the weir or dam; that the level of no discharge is determined by the horizontal plane through the crest of a weir, dam or natural bar; that two new hydraulic terms may be used, viz.: Permanent Area, or that part of transverse section below the plane of no discharge, and Ruling Depth or the depth of the plane below the surface. Formulæ are then suggested in application of these considerations. The paper was discussed by Messrs. T. C. Clarke, Ashbel Welch, F. Collingwood, Joseph P. Davis and Charles E. Emery.

ENGINEERING NOTES.

Submarine Telegraphy.—Attention has been prominently drawn to the danger that submarine cables in certain places are subject to, and to some of the delays to which the vessels engaged in the laying and the repair of submarine cables are effected. It appears from a list that has been compiled that there are not fewer than twenty vessels, mostly the property of British companies, engaged in the work of cable laying and repairing. Their tonnage varies from 369 tons to 4,935 tons, the total being 45,629 tons gross. This fact in itself shows the extent of the operations that must be carried on, and the greater importance and the value of the work that the cables so laid are effecting from year to year in the world. It has been suggested that it would minimize the danger to cables, that have of late been prominently brought before the public, if laws were passed to secure rights to the "first comers" on cable "ground," and that the vessels engaged in relaying or repairing should be free from certain Custom House formalities that now press upon them, and causing delay to the vessels, impede seriously the telegraphic communication and the work and commerce of the whole of the world. A case is reported where it has been necessary to land telegraphic instruments for testing, value about £120, and in addition to formalities that caused delay, dues were charged on these to the amount of £118. It is evident then that when the importance of the work of these repairing vessels is borne in mind, that they should have special privileges, for though their's is a commercial mission nominally, it is in reality one that is much more an international one—one that is for the benefit of the whole of the subjects of the nations to be connected together "under the green translucent wave." The vessels of telegraphic companies are practically little more than Queen's messengers—they are the emissaries that keep in order the means of communication between all nations, and they sought to pass unquestioned—their flags being flags of truce. It is to be hoped that in some way there may be a speedy amelioration of the laws that press on the cable vessels, and it would not be too much to express the hope that the representatives of all nations should be appealed to to facilitate this needful work. Up to the present time the owners of the cables have not received too great a return for the capital they have put into the cables, and that capital is invested in an article peculiarly subject to assaults, and yet one that is increasingly becoming the mode of communication between nations severed by the sea, but connected by the cable. It is, therefore, in the highest interest of the nations and the peoples that there should be every facility for the repairing of broken cables, and that the needful works should be gone on with without the stoppage by red tapeism. We have yet only partly reaped the benefits of the submarine cables, for as the system becomes more and more extended, so the efficiency of the whole is increased, and the value of the communication enlarged. It is possible that the cost of telegraphy under the sea may be much further cheapened, but one of the essentials to that further reduction is the facility that is now claimed, so that each cable may perform as much work as possible, and that the revenue of the companies may be increased by the cessation as much as possible of stoppages. There is a further question that may some day come up, whether the Governments of the world ought not to possess international cables of their own, by purchase; but that question can scarcely be said to be as yet "within the range of practical politics," whilst that we have alluded to is not only so, but is one that presses for early solution.

Excavators and Dredgers in Panama. —Contradictory accounts have been published from time to time of the machinery to be employed for the excavations in the Panama Canal works. The following description of them may be taken as an official one, having been published by the company itself. The excavator, designed by M. Couvreux, is, in fact a dredging machine on dry land, with the necessary modifications to suit the different nature of its work. The excavator, however, cannot stand over its work like a floating dredger, and the endless chain with buckets is therefore placed at one side of it, and nearly horizontal, although some inclination is given to the chain according to the slope of the ground and nature of the soil. The buckets are then driven along the slope of the cutting, scooping out the earth or cutting it away like a succession of planes, and throwing it out on the other side of their round. The excavator can be placed either on the level from which the excavation is to be made, or—in case of a mass of earth to be removed—on the level down to which the soil is to be brought. In every case it stands by the side of the place of work, upon rails of the normal gauge, and moves along continuously while in action. After it has reached the end of the rails they have to be shifted, either to bring it again alongside of the remaining mass to be leveled, or to remove it further from the trench. The great weight of the chain of buckets, with all its apparatus, coming entirely upon one side, and the tremendous strain of the work, so unequally distributed, made the question of securing the balance of the machine a very difficult one. This has been effected by various expedients, of which the principal has been the use of a third wheel on each of the four axles, working on a third rail 20 inches within the outer rail on the side of the chain. The excavator is furnished with two engines; one of 20 horse power drives the chain, the other, of only 4 horse power, moves the machine on the rails. The appearance of the whole is like a very tall locomotive, and the total weight is somewhat over 44 tons. The buckets contain about 6 cubic feet each, and their number varies according to circumstances. They can be driven to the depth of 16 feet. The excavator works at the rate of 80 turns per minute, and on an average (allowing for loss of time) excavates and loads on trucks 84,600 cubic feet of earth per day, thus doing the work of 600 laborers. It only requires the services of a driver, stoker, and two workmen for various purposes, besides the men who remove the rails, which only takes up a portion of their time. The dredging machines employed in this work are of great size and power; they are 110 feet long by 21 feet broad, and weigh when empty about 98½ tons. The buckets contain about 10 cubic feet each; they can be driven nealy 30 feet deep, and lift their contents to such a height that they can be shot to a distance of 133 feet. The average of work done is nearly as great as that of the excavator.

Proposed tunnel under the Thames.—Some of the local authorities in the east end of London are much exercised at a rumor that the Metropolitan Board of Works have a project under consideration for a tunnel from the Whitechapel road to the south side of the Thames, this being, in their opinion, the best method of satisfying the great need of communication. It would probably be more correct to say that the tunnel is proposed in order to avoid the opposition of the city authorities, who, apparently, will consent to nothing—however much for the good of the metropolis—which may touch the vested interests of Billingsgate and Thames street. At any rate in the East of London, beyond the city, the need is for the bridge, and not for a tunnel, and this view is to find expression at the next meeting of the Whitechapel District Board of Works on Monday, the 19th inst., when Mr. William Smither, the well-known carrier and local representative, is to move: "That in the opinion of this board the proposed means of communication between the north and south side of the Thames below London Bridge should be a low-level bridge." If London had a representative government like every other town and city in the empire, a resolution such as this would have had effect long ago.

Submarine Tunnels.—Since the works in connection with the Channel Tunnel experiments were commenced at the new heading at Shakespeare's Cliff, the operations have been so successful that the first quarter of a mile is now completed. What looks especially encouraging is that the engineers are able to gradually increase the rate of boring, which has attained the excellent average of thirty-six feet per day; and in addition to this the soil is now quite dry, there being a total absence of springs, the presence of which proved a source of much delay in the Abbot's Cliff heading. There are now about eighty men engaged on the works. They are employed in two night and day shifts, but it is proposed shortly to have an extra shift, making eight hours each in order to expedite the work. No boring is done on Sunday, the men being chiefly employed on that day in lengthening the double line of metals in which the trollies carrying the debris travel. The boring has now advanced several yards under the sea in the direction of the Admiralty Pier at Dover. With regard to the Mersey Tunnel, we are informed that the second shafts on the Liverpool and Birkenhead sides, from which the main tunnel has to be driven, have been completed on each side for some time, and the first section of the tunnel is now being excavated on each side, and will be finished by 1st of January. The whole length of the heading on the Liverpool side has been enlarged previous to bricking, and that at Birkenhead is now undergoing the same process, while the Liverpool heading is being driven forward at the usual rate of eleven to twelve yards per week. About a quarter of the whole length of the heading from shaft to shaft has now been driven without any change in the character of the solid red sandstone rock through which it passes. Both the tunnel and the heading will be bricked throughout with several courses of brick. New Ferry bricks have been selected for the outer rings, and Staffordshire blue bricks for the inner. The whole will thus be of the best quality.

The Destruction of Calf Rock Lighthouse.—It is fortunately seldom that any serious disaster in connection with the Lighthouse Service of the United Kingdom has to be recorded, which fact is a silent testimony to the efficiency and permanence of the general arrangements for the marking of our coasts. It is therefore not without a feeling of pain that we have to refer to the recent accident at the lighthouse on the Calf Rock, near Bearhaven, on the southwest coast of Ireland. This lighthouse was completed in 1866; the tower was of cast iron, lined with brick, 75 feet high, and 21 feet diameter at the base. In January, 1869, a very severe storm took place, during which a portion of the lantern gallery was carried away. Upon this warning as to the exceptionally heavy seas which break on the rock, it was thought desirable, after professional inspection, to strengthen the tower for half its height with an external casing of cast iron, the space between the old and new casings to be filled in with concrete, thereby increasing the diameter to 30 feet at the base, and to reduce the overhanging lip of the gallery so as to offer less obstruction to the waves which might strike the tower. This work was duly carried out, and some small houses were erected on the rock for the protection and convenience of the keepers. Since that period, 1870, nothing alarming has occurred, although it is reported that the sea frequently broke with very great fury upon the rock, the waves at times running up and striking the upper part of the tower with tremendous force. Both this rock and the Fastnet to the south are exposed to the full strength of a southwest gale, there being nothing whatever to break the force of the wind itself rushing across the vast expanse of the Atlantic, nor of the momentum of the waves established by the wind and which "come home" upon these rocks with indescribable violence. The catastrophe now to be recorded is that during a storm on the morning of the 27th November, the whole of the upper part of the tower above the new casing was carried away, the keepers having to run for their lives. Fortunately no life was lost, but as the men could not get off the rock, they were compelled to wait there during a long continuance of bad weather, it being impossible for a boat to get near the rock, and provisions having to be conveyed to them by various expedients. The men managed to obtain some shelter in the small houses already mentioned, but were in a condition of great peril. A change of wind and consequent quieting of the sea at length enabled the men to be taken off, after eleven days' imprisonment, during which they endured much exposure and hardship. With praiseworthy alacrity the Commissioners of Irish Lights have arranged for the exhibition of a light, similar in character to that extinguished, from Dursey Island, and not too soon can so valuable a light be replaced, for no one knows what further disasters may result from its absence. As regards the cause of the giving away of the tower in connection with its design and construction, no opinion can at present be formed, but no doubt the matter will be fully investigated in order that the defect, if any, may be brought to light, and a recurrence of such a catastrophe prevented.—*Nautical Magazine.*

According to news by recent mail, the new harbor works at Madras had been seriously damaged, and the cranes at the ends of the northern and southern piers were swept away. The top row of blocks, for about 2,500 feet from the end of each pier, was carried away, and the extremities of the piers have settled down about 2 feet. The steam hopper barges Salisbury and Hobart which were engaged in laying down moorings in the harbor, foundered. Their European captain and about fourteen natives were drowned.

The directors of the Midland Railway Company are considering a scheme for lighting the entire length of the Erewash Valley stations, junctions, branches, and sidings by electricity. It is proposed to light as far as Alfreton by one engine, fixed at Chesterfield, and as far as Pye Bridge by another fixed at Nottingham, the stations being at comparatively short distances apart.

RAILWAY NOTES.

One thousand miles of railway are now open for traffic in New South Wales, of which 147 were opened during the current year. Four extensions, aggregating 225 miles, would be laid down next year. The increase of population in the colony since the passing of the Land Act in 1860 was 50 per cent., being greater than in the United States, where the increase had never been more than at the rate of 37 per cent in ten years.

In a country having a well-developed railway system the number of persons occupied with railway work is such as would form a large army. Thus, according to the *Deutsche Industrie Zeitung*, the number of officials and workmen on the German lines in the end of 1879 was 272,831, while the corresponding number for France the previous year was 182,983. For every 100,000 of the population, 611 in Germany and 493 in France were engaged on railways. The greater number in the former case is explained by the fact that, in relation to surface and population, Germany has a larger network of railways than France. For every 100 kilometers of line the *personnel* is in Germany about 834; in France 827; therefore nearly the same. Dividing the *personnel* into four groups, it appears, first, that the number of persons occupied with "general management" is in Germany about three times what it is in France per 100 kilometers of line, this being mainly due to the greater division of the railway system in Germany, where there are seventy-four railway lines with separate management, as against twenty-one in France. Next, a relatively less number of persons is engaged permanently in Germany than in France in the line service—second group—and in traffic and commercial service—third—whereas in train and workshop service—fourth—more persons are engaged in Germany. The traffic on the German lines is not, however, busier than on the French; but for the conveyance of the same number of persons, or the same quantity of goods, the same distance, a larger *personnel*—in this fourth group—is employed in Germany. The French statistics show, *inter alia*, that 68,865 persons who had been in the army, were engaged on French railways at the date specified; also, 13,554 women. The former are pretty regularly distributed among all the four groups, and the latter are most largely engaged in line service.

The Westinghouse Brake.—A limited company has been formed in England and has taken over all the property, rights, and interests of the Westinghouse Continuous Brake Company, which was an American organization. The directors of the new company are Mr. George Westinghouse, chairman; Sir Henry Tyler, vice-chairman; Sir Thomas Douglas Forsyth, K. C. S. I., and Capt. Francis Pavey. The Westinghouse automatic brake has, we are glad to say, made progress. It is now in use on fourteen railways in the United Kingdom, being fitted to 1,087 engines, and 7,719 carriages. In France it is in use on eight railways, and is now, or will be in a very short time, fitted to 1,416 engines, and 7,193 carriages. It is also in use in Austria, Germany, Russia, Holland, Italy, Sweden, India, New South Wales, South Australia, and Queensland. In the United States it was up to September the 30th, 1881, fitted to 3,435 engines and 12,270 cars. The grand total for the world is—engines, 6,599; carriages, 29,562. In sixteen months, that is to say, since July, 1880, there have been fitted 3,822 engines, and 16,060 carriages. With the non-automatic brake, there are 2,579 engines, and 11,889 vehicles fitted in the United States, principally to goods trains. Including both types, there are now fitted 9,236 engines, and 41,350 vehicles. A brake which is in such extended use must be good. The experience acquired with it is enormous, and yet we find English railway companies halting between two opinions, and asserting that they cannot find a satisfactory brake. Under the circumstances this sounds like nonsense, and it is quite certain it will be impossible for any railway company to obtain by its unaided efforts during a few months, a twentieth part of the experience already gained by the Westinghouse Brake Company. Facts constitute very stubborn arguments, and the way in which the Westinghouse brake has made its way in spite of a great deal of opposition, is a fact constituting a most powerful argument in its favor.

IRON AND STEEL NOTES.

The Dephosphorization Process in Germany.—At the last meeting of the Iron and Steel Institute of Germany held at Düsseldorf, Director Brauns, of the Dortmund Union Steel Works, read a paper on "The Economical Aspects of the Thomas-Gilchrist Process in Germany." The author stated that the process had been worked regularly at the Union works since May last, and that tests were made on a sample from every charge. The experience gained in this way confirmed that obtained by the Rhenish, Hörde, and other works, that there was no difficulty in obtaining uniformly good work as regularly as with ordinary Bessemer steel. They had, moreover, demonstrated that the Thomas steel presented special advantages for the manufacture of railway sleepers, plates, soft steel for wire, &c., even where local circumstances were such as to enable hematite steel to be made as cheaply as dephosphorized steel. The result was that this dephosphorized ingot iron would for very many purposes take the place of puddled iron, and that such of the iron that was now imported into Germany for ship plates and other uses would be replaced by the cheaper and better dephosphorized steel manufactured in Germany. The difficulty of obtaining suitable iron to treat by the basic process has been greatly exaggerated. Experience showed that not only by reason of its being possible to use phosphoric ores, but in every other respect, the manufacture of a suitable basic pig was far easier and cheaper than the manufacture of ordinary Bessemer iron. It was found that the output of a blast furnace on Thomas-Gilchrist pig iron would exceed by from 25 to 30 per cent. the production of a blast furnace on Bessemer pig; while the campaign of the furnace working on the latter would be much shorter. White iron is generally preferred to grey iron, and the phosphorus may with advantage be kept between 1½ and 1¾ per cent. The ore districts of Germany that would most benefit by the Thomas-Gilchrist process are Lorraine, Luxemburg, the brown ore region of Bonn, and the black band region of Dortmund; the Ilsede and Upper Silesian and Bavarian works would also be largely benefited. In the discussion that followed, Director Grass stated that his works found the extra costs on the Thomas-Gilchrist process to be 7s. a ton. This would make the Thomas Bessemer steel about 13s. a ton cheaper than hematite Bessemer steel in Germany, where phosphoric iron is at least 20s. a ton cheaper than Bessemer iron.

M. Forquignon, who has published an extensive series of researches upon malleable iron and the reheating of steel, attaches special importance to the following conclusions: (1) Malleable iron always contains amorphous graphite; (2) a casting may lose carbon and yet remain brittle if the original quantity of graphite is not increased; (3) a casting may become malleable without losing any sensible portion of its carbon; (4) if silicium is added to manganesian castings they are improved by reheating; (5) hydrogen and nitrogen may unite with the carbon of a casting so as to make it malleable without the production of graphite; (6) the breaking load is always more than doubled, sometimes more than quadrupled, by annealing—it increases with the duration of the heating, very rapidly at first and then very slowly; (7) ductility generally increases with the resistance to breaking, but after a certain limit it has a slight tendency to diminish.

ORDNANCE AND NAVAL.

A New Machine Gun—The Ordnance Committee recently witnessed at Woolwhich the trial of a new machine gun, for wich a merit is claimed, far surpassing that of any of its many predecessors. From all of these it differs materially, both in appearance and principle; but, in having ten parallel barrels on a line, it bears a somewhat close resemblance to the well-known French "infernal machine." It is fed by a frame filled with cartridges, 150 in number, and ten in a row. This is dropped into a groove at the breech, and worked to and fro by a lever, each movement forward discharging one row of ten shots, and each movement backward withdrawing the empty cases. By a simple mechanism, adjusted before commencing action, and alterable at will, the barrels can be elevated and traversed right and left as it is being fired, and in point of rapidity it has never been excelled, the ten barrels exploding almost simultaneously, and reloading again as quickly as the hand can move. The sample gun under experiment was, however, unfortunately weak in springs provided for firing the percussion caps, and there were consequently a great many misfires.

The following are the dimensions of some of the large modern ships:—The City of Rome is 546 ft. in length; the Great Eastern, 676; the Great Eastern in breadth is 82 ft. 8 in.; depth, 60 ft., with a registered tonnage, excluding engine space, of 13,343. She has stowage for cargo to the extent of 6000 tons, and the capacity in her coal bunkers is 10,000. When loaded she draws 30 ft. of water. The City of Rome is 52 ft. 6 in. broad, and 34-38 ft. deep, with a gross tonnage of 8415. While she is thus 16 ft. longer than the Servia and 6 in. more beam, the Cunarder is actually 6 ft. 9 in. deeper, and is said to be able to carry a few tons more cargo. The Cunard Liner Gallia is 450 ft. long and 46 ft. broad, with a gross tonnage of 5000; the Arizona, 466 ft. long and 46 ft. broad, with a gross tonnage of 5500; the Orient, 460 ft. long and 46 ft. 6 in. broad; the Parisian, 450 ft. long; the Anchor Liner, Furnessia, is 445 ft.; State of Nebraska, 395; Notting Hill, 420; Alaska, 525; Spartan, 370; Drummond Castle, 375; City of Calcutta, 400; Kansas—building—435; Austral—building—400; the Clyde, 385; and several of the White Star Liners about 400 ft. long. One of the Cunard steamers, named the Aurania, now under construction in the yard of Messrs. James and George Thomson, is to be of somewhat unusual dimensions, some 485 ft. long and 57 ft. broad, with a tonnage of 7500; and another, the Pavonia, will carry 5500 tons.

In the course of November 22 vessels, with an aggregate tonnage of 31,170, have been launched from the Clyde ship-building yards as compared with 14 vessels of 26,300 tons in November, 1880. The work of the eleven months consists of 215 vessels of 290,039 tons, against 206 vessels of 213,130 tons in the same period of last year. A large number of new contracts have been placed during the month.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

Journal of the Military Service Institution of the United States. Vol. 2, No. 8.

Monthly Weather Review for December. Washington: Government Printing Office.

From the institution of Civil Engineers we have received through the kindness of Mr. James Forrest, Secretary:

Steel for Tires and Axles. By Benjamin Baker, M.I.C.E.

Experiments with Portland Cement. By Henry Faija, A.M.I.C.E.

The Weights of Framed Girders and Roofs. By Joseph H. W. Buck, M.I.C.E.

A History of the St. Louis Bridge—containing a full account of every step in its construction and erection, and including the theory of the Ribbed Arch and the Tests of Materials. By C. M. Woodard, Thayer Professor of Mathematics and Applied Mechanics, and Dean of the Polytechnic School of Washington University. St. Louis: G. J. Jones & Co. Price, cloth, $20.00; half bound, $25 00.

The title of this sumptuous volume idicates with sufficient fullness the scope of its contents. It is proper to add, however, that the style of the book, of its typography and illustrations, is quite commensurate with the great engineering work which it describes.

Of so great a work it is difficult to convey an adequate idea of its contents in the brief space of a *notice*, but an outline of the plan may be profitably presented.

The author at the outset discourses upon the "Basin and Regimen of the Mississippi River." This constitutes the first chapter. As it is a complete essay in itself, and a valuable one, it will be reprinted shortly as an article for this magazine. Apart from the questions of hydraulics which invest the natural history of such a great river with intense interest, the geographical features alone are sufficient to challenge the attention of intelligent readers everywhere. The area drained by the stream that flows under the great bridge is eighty-eight times the area of Massachusetts; or to state it in a more striking manner, the area whose drainage supplies the river at St. Louis equals the united areas of the basins of the Clyde, the Thames, the Seine, the Garonne, the Rhone, the Rhine, the Vistula, the Po, and the Elbe.

The "Historical sketch of attempts to bridge the Mississippi at St. Louis," and "The organization and work of the St. Louis and Illinois Bridge Company," which forms chapters 2d and 3d, are of local rather than general interest, although as the main features of other plans than the accepted one are discussed, and the objections to the present bridge are presented, the reader will doubtless be interested to find a certain likeness to the growth of other engineering projects of unusual magnitude.

The discussion over the merits and demerits of the plans is, perhaps, more fully expressed in the fourth chapter, in which the history of the organization of a rival company is related, and the final consolidation of the two.

"The West Abutment—the first report of the Chief Engineer," are the subjects of the fifth chapter. The practical beginning of the great work is completely described.

The illustrations distributed through the text are excellent and numerous. The character of the bed of the river is carefully analyzed, and the theory of the proposed bridge and of its supporting piers elaborately expounded.

Chapters six and seven relate to "Financial Matters, The Sinking of the Three Great Piers, Contracts, Controversies and Specifications." The portion relating to controversies is interesting reading, and all of it profitable.

Chapters eight and nine, on "the Construction of Anchor Bolts and Staves," and "Rolled Iron Work and Steel Envelopes" contain much valuable information regarding the tests applied to iron and steel members, of unusual dimensions and of varied composition. The experiments on chrome steel are of great interest and value. It is not merely the tabular statement of experimental trials that is here related, but the entire history of the solution of some exceedingly difficult problems in construction.

The encounter with similar difficulties is graphically related in the four succeeding chapters, all relating to the making and testing of separate important parts of the structure.

Chapter 10 records the "Reports and Suggestions of Mr. James Laurie, C.E.;" chapters 11 and 12 the "Manufacture of Steel Couplings," and chapter 13 to "The Work at the Keystone Shops."

With chapter 14 begins the story of the erection of the work. Chapters 15 and 16 continue the description, and detail the history of the closing of the west span, and then of the center and east spans in succession. The method of balancing the parts of the bridge on the pier is most fully described and illustrated by views taken at different stages of the progress.

The completion of the bridge and the account of the tests are recorded in chapter 17.

This is as nearly as possible the middle of the book. Eleven chapters more are devoted to the special discussion of subjects relating to the work, but which to have presented earlier would have encumbered the historical narrative.

These are the Sinking of the East Pier, Sinking of the West Pier, Sinking of the West Abutment, Stone Approaches, Ice Breakers, The Physiological Effects of Compressed Air (published from advance sheets in the January number of this Magazine), Investigations and Reports of the Board of Engineers of the United States Army, The Method of Erection, The Strength and Elasticity of Materials, The theory of the Ribbed Arch, Stability of the Foundations, Tables of Dimensions and Cost.

All of these special subjects are valuable to the engineer. One of them, The Theory of the Ribbed Arch, is a mathematical analysis of the structure.

The large plates, forty-seven in number, form a fitting embellishment to this beautiful volume.

Simple Hydraulic Formulæ. By T. W. Stone, Civil Engineer. London: E. & F. N. Spon. Price $2.50.

This is a collection simply of the most useful formulæ in hydraulic engineering.

They are given under the following heads:

Flow over Weirs, Discharge Through Orifices, Discharge Through Short Tubes, Flow Through Long Pipes, and Distribution Pipes for Towns, Flow from Jets, Flow Through Canals, Rivers, and Aqueducts.

The appendices contain valuable tables. The whole forming a handy book, which, to the practical man, will be a welcome substitute for the large treatise.

Water; Its Composition, Collection, and Distribution. By Joseph Parry, C.E. London: Frederick Warne & Co. Price $2.00.

"This book has been written (says the author) with a desire to give information that may be useful to the public in reference to Water and Water Supply; in deciding upon the merits of water schemes and methods of distribution, and in the selection, construction, and management of the numerous water appliances in which consumers are interested."

The several chapters treat in succession of the following subjects: Water, Composition of Water and Sources of Supply, Purification of Water, Modern Water Works, Distribution of Water, Water Rents, Appliances for Domestic Supplies, Waste of Water, Rural Supply, Water for Trade Purposes, Prevention of Waste.

An Elementary Treatise on Mensuration. By Geo. Bruce Halsted, A.B., A.M., and ex-Fellow of Princeton College; Ph.D. and ex-Fellow of Johns Hopkins University. Instructor in post graduate mathematics, Princeton College.

The author's preface reads thus: "This book is primarily the outcome of work on the subject while teaching it to large classes.

"The competent critic may recognize signs of a Berlin residence; but a considerable part, it is believed, is entirely new.

"Special mention must be made of the book's indebtedness to Dr. J. W. Davis, a classmate with me at the Columbia School of Mines." * * * *

This seems but scant recognition of the fact that the best parts of the book are but reprints of contributions to VAN NOSTRAND'S MAGAZINE, by J. Woodbridge Davis, C.E. Whole sections are reproduced verbatim, and the diagrams literally copied from Vols. XX. and XXI. of this Magazine, with no other hint of their origin than that afforded by the above reference to "Dr. J. W. Davis."

The most conspicuous of these borrowings are as follow: Pages 40 to 45 inclusive, on the measurement of Plane Areas, are mostly copied from the April No. of VAN NOSTRAND'S for 1879.

Pages 99–105, 107–120 on the measurement of Volumes, are mostly from the same source.

Chapter VI. on the Applicability of the Primoidal Formula, is mostly from a thesis of Mr. Davis, from which one of his magazine articles was condensed, and in the more important parts is literally copied. The last section of this chapter, one page only, seems to be the only original portion.

Chapters VII. and VIII., the last of the treatise proper, have been prepared from several sources: Boole's Calculus of Finite Differences, and the Mathematical Monthly among others, but by far the greater portion is from VAN NOSTRAND'S MAGAZINE for May, June, July, and October, 1879.

No objection is made to the contents of this book. The material is well selected and well enough arranged. It is exceedingly well printed and but for the fact that borrowed material is made to pass for original work, it would be a creditable performance.

THE ELEMENTS OF FIELD FORTIFICATIONS. By J. B. Wheeler, Professor of Civil and Military Engineering in the United States Academy at West Point, Brevet-Colonel United States Army. New York: D. Van Nostrand Price $1.75.

This book was prepared for the use of the Cadets of the West Point Military Academy.

"The endeavor has been made," says the preface, "to state concisely and plainly the principles upon which the art of fortification is based, and to give all information likely to be of practical use to a young officer while serving in the field, all unnecessary details have been avoided, leaving explanations and illustrations of that kind to be introduced into the class room.

"The elementary form of the work and the method of treatment of the subject are based upon the assumption, that the readers of the book are beginners and know nothing of the principles of fortification."

The separate topics are:

General Principles and Definitions, Elements of the Profile of a Fortification, Dimensions and Inclinations given to the Lines and Slopes of a Parapet, The Trace of a Field Fortification, Field Works, Lines, Continued Lines, Lines with Intervals, Size of a Field Work, The Number of its Garrison and the Selection of its Trace, Construction of Field Works, Revetments, Defilade, Interior Arrangements made in a Field Works, Arrangement of the Parapet, Arrangements for Sheltering the Troops, For Affording Communications, For the Health and Comfort of the Garrison, Arrangement Exterior to the Parapet, Ditch Defenses, Obstacles, Sites upon Irregular Ground, Bridge Heads, Hasty Intrenchments, Attack and Defense of Field Fortifications, Siege Works, Military Bridges, Railroads.

The illustrations, ninety-seven in number, are distributed throughout the book.

The book looks inviting, even to readers having only a remote interest in military matters, by the appearance that it bears of imparting instruction in a simple, direct, and logical manner.

THE THEORY OF OUR NATIONAL EXISTENCE, AS SHOWN BY THE ACTION OF THE GOVERNMENT OF THE UNITED STATES SINCE 1861. By John C. Hurd, LL.D. Boston: Little, Brown & Co. Price $4.00.

The author is well known through his previous work, "The Law of Freedom and Bondage in the Unites States." The reputation already won by the author among jurists justifies the belief that the present work will be widely read.

ERRATUM.

On page 173 of the present volume (Feb. No.) in the second column, the 25th and 26th lines (at the end of the notice of "Pressure of Earthwork"), should have been at the end of the previous article, so as to form 4th and 5th lines in the same column.

MISCELLANEOUS.

THE surveying party under General Fielding, which started in June last on the survey exploration for determining the best route for the proposed Trans-Australian railway from Roma, Queensland, to Fort Parker, in the Gulf of Carpentaria, has reached the latter end of the journey, and will probably return to Brisbane by the middle of this month. The results of the preliminary run through the country made by Mr. R. Watson, M.I.C.E., for the purposes of a report to the Queensland Government, was made in the first six months of last year, and the results were described in English papers, in September last. Queensland railways are 3ft. 6in. gauge, and before this great line is made it is to be hoped that some standard gauge for the whole of Australia will be arrived at by the several colonial Governments.

THE man who will render cranks unnecessary will confer a boon on the nation. In a few years cranks cost nearly as much as some of the ships that want them. Serious cracks were discovered last week in the necks of the midship high-pressure crank of the Jumna, as well as in the after crank. A spare crank is always kept in hand at Portsmouth, but, though it has been determined to work night and day to get it ready, the fitting of the eccentrics and other parts will take about a month to complete.

Five Dollars per annum.

Whole No. 160. Volume 26. No. 4.

Van Nostrand's

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APRIL, 1882.

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VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLX.—APRIL, 1882.—VOL. XXVI.

ON THE MECHANICAL PRODUCTION OF ELECTRIC CURRENTS.

From "Engineering."

The object of these articles is to lay down in the simplest and most intelligible way the principles which are concerned in the mechanical production of electric currents. Every one knows now that electric lights are produced from powerful currents of electricity generated in a machine containing magnets and coils of wire, and driven by a steam engine, or gas engine, or water wheel. But of the thousands who have heard that a steam engine can thus provide us with electric currents, how many are there who comprehend the action of the generator or dynamo-electric machine? How many, of engineers even, can explain where the electricity comes from, or how the mechanical power is converted into electrical energy, or what the magnetism of the iron magnets has to do with it all? Take any one of the dynamo-electric machines of the present date—the Siemens, the Gramme, the Brush, or the Edison machine—of each of these there exist descriptions excellent in their way, and sufficient for men already versed in the technicalities of electric science. But to those who have not served an apprenticeship to the technicalities—to all but professed electricians—the action of these machines is almost an unknown mystery. As, however, an understanding of the how and the why of the dynamo-electric machine or generator is the very A B C of electrical engineering, an exposition of the fundamental principles of the mechanical production of electric currents demands an important place in the current science of the day. It will be our endeavor to expound these principles in the plainest terms, while at the same time sacrificing nothing in point of scientific accuracy or of essential detail.

The modern dynamo-electric machine or generator may be regarded as a combination of iron bars and copper wires, certain parts of the machinery being fixed, whilst other parts are driven round by the application of mechanical force. How the movement of copper wires and iron bars in this peculiar arrangement can generate electric currents is the point which we are proposing to make clear. Friction has nothing to do with the matter. The old-fashioned spark-producing "electrical machine" of our youthful days, in which a glass cylinder or disc was rotated by a handle whilst a rubber of silk pressed against it, has nothing in common with the dynamo-electric generator, except that in both something turns upon an axis as a grindstone, or the barrel of a barrel-organ may do. In the modern "dynamo" we cannot help having friction at the bearings and contact pieces, it is true, but there should be no other friction. The moving coils of wire or "armatures" should rotate freely without touching the iron pole pieces of the fixed portion of the machine. In fact friction would be fatal to the action of the "dynamo." How then does it act? We will proceed to explain without further delay. There are, however, three fundamental principles to be borne in mind if we would follow the explanation clearly from step to step, and these three principles must be laid down at the very outset.

1. The first principle is that the existence of the energy of electric currents, and also the energy of magnetic attractions, must be sought for not so much *in the wire* that carries the current, or *in the bar* of steel or iron that we call a magnet, as *in the space that surrounds* the wire or the bar.

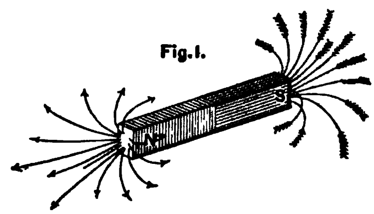
2. The second fundamental principle is that the electric current is, in one sense, quite as much a *magnetic* fact as an electrical fact; and that the wire which carries a current through it has magnetic properties (so long as the current flows) and can attract bits of iron to itself as a steel magnet does.

3. The third principle to be borne in mind is that to do work of any kind, whether mechanical or electrical, requires the expenditure of energy to a certain amount. The steam engine cannot work without its coal, nor the laborer without his food; nor will a flame go on burning without its fuel of some kind or other. Neither can an electric current go on flowing, nor an electric light keep on shedding forth its beams, without a constant supply of energy from some source or other.

The last of these three principles, involving the production of electric currents for the work they are to do and to the energy expended in their production, will be treated of separately and later. Meantime we resume the task of showing how such currents can be produced mechanically, and how magnetism comes in in the process.

Surrounding every magnet there is a "field" or region in which the magnetic forces act. Any small magnet, such for example as a compass needle, when brought into this field of force, exhibits a tendency to set itself in a certain direction. It turns so as to point with its north pole toward the south pole of the magnet, and with its south pole toward the north pole of the magnet; or if it cannot do both these things at once, it takes up an intermediate position under the joint action of the separate forces and sets in along a certain line. Such lines of force run through the magnetic "field" from one pole of the magnet to the other in curves. If we define a line of force as being the line along which a free north-seeking magnetic pole would be urged, then these lines will run from the north pole of the magnet round to the south pole, and pass through the substance of the magnet itself. In Fig. 1

Fig. I.



a rough sketch is given of the lines of magnetic force as they emerge from the poles of a bar magnet in tufts. The arrow heads show the direction in which a free north pole would move. These lines of force are no fiction of the imagination like the lines of latitude and longitude on the globe; they exist and can be rendered visible by the simplest expedients. When iron filings are sprinkled upon a card or a sheet of glass, below which a magnet is placed, the filings set themselves—especially if aided by a gentle tap—along the lines of force. Fig. 2 is a reproduction from nature of this very experiment, and surpasses any attempt to draw the lines of force artificially. It is impossible to magnetize a magnet without also in this fashion magnetizing the space surrounding the magnet; and the space thus filled with the lines of force possesses properties which ordinary unmagnetic space does not possess. These lines give us definite information about the magnetic condition of the space where they are. Their direction shows us the direction of the magnetic forces, and their density shows us the strength of the magnetic forces; for where the force is strongest there we have the lines of force most numerous and most strongly delineated in the scattered filings. To complete this first consideration of the magnetic

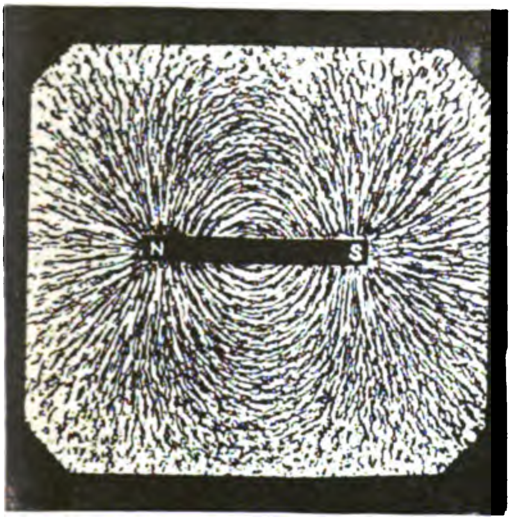


Fig. 2.

field surrounding a magnet, we will take a look at Fig. 3, which reproduces the lines of filings as they settle in the field

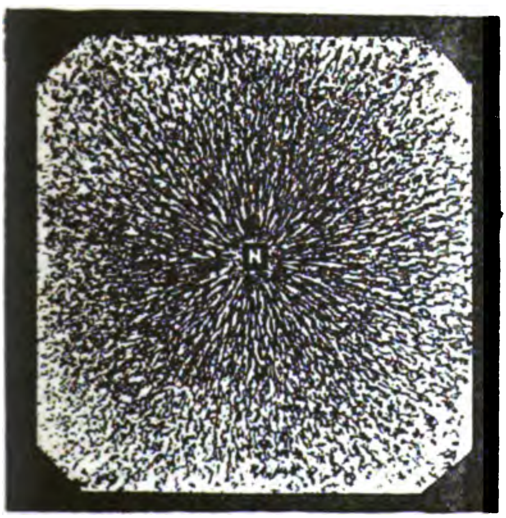
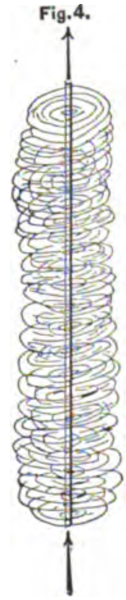


Fig. 3.

of force opposite the end of a bar magnet. The repulsion of the north pole of the magnet upon the north poles of other magnets would be, of course, in lines diverging radially from the magnet pole.

We will next consider the space surrounding a wire through which a current of electricity is flowing. This wire has magnetic properties so long as the current continues, and will, like a magnet, act on a compass needle. But the needle never tries to point toward the wire, its tendency is always to set itself broadside to the current and at right angles to it. The "field" of a current flowing up a straight wire is, in fact, not unlike the sketch shown in Fig. 4, where instead of

Fig. 4.

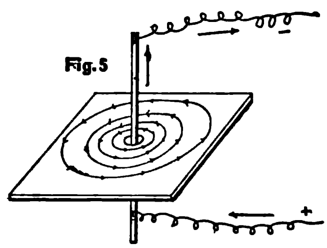


tufted groups we have a sort of magnetic whirl to represent the lines of force. The lines of force of the galvanic field are, indeed, circles or curves which enclose the conducting wire, and their number is proportional to the strengh of the current. In the figure, where the current is supposed to be flowing up the wire (shown by the dark arrows), the little arrows show the direction in which a free north pole would be urged round the wire; * a south pole would, of course, be urged round the wire in the

* It will not be out of place here to recall Ampere's ingenious rule for remembering the direction in which a current urges the pole of a magnetic needle. "Suppose a man swimming in the wire with the current, and that he turns so as to face the needle, then the north pole of the needle will be deflected towards his left hand."

contrary direction. Now, though when we look at the telegraph wires, or at any wire carrying a current of electricity, we cannot *see* these whirls of magnetic force in the surrounding space there is no doubt that they exist there, and that a great part of the energy spent in starting an electric current is spent in producing these magnetic whirls in the surrounding space. There is, however, one way of showing the existence of these

Fig. 5



lines of force; similar, indeed, to that adopted for showing the lines of force in the field surrounding a magnet. Pass the conducting wire up through a hole in a card or a plate of glass, as shown in Fig. 5, and sprinkle filings over the surface. They will, when the glass is gently tapped, arrange themselves in concentric

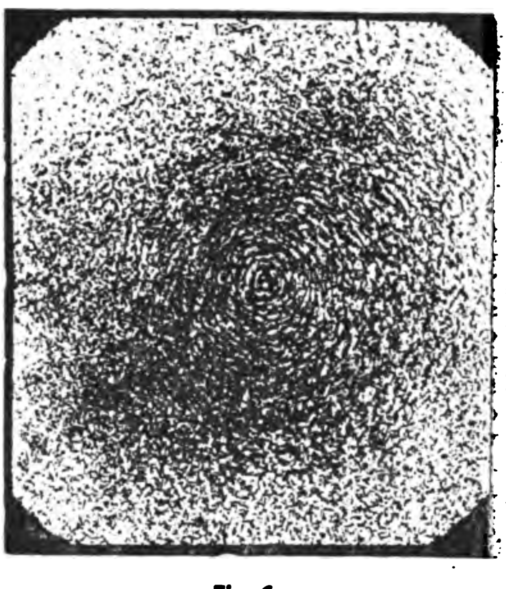


Fig. 6.

circles, the smallest and innermost being the best defined because the magnetic force is strongest there. Fig. 6 is an actual reproduction of the circular lines produced in this fashion by iron filings in the field of force surrounding an electric current.

This experimental evidence must suffice to establish two of the three fundamental points stated at the outset, for they prove conclusively that the electric current may be treated as a magnetic phenomenon, and that both in the case of the pole of a magnet, and in that of the wire which carries a current, a portion, at any rate, of the energy of the magnetic forces exists outside the magnet or the current, and must be sought in the surrounding space.

Having grasped these two points, the next step in our argument is to establish the relation between the current and the magnet, and to show how one may produce the other.

If we wind a piece of copper wire into a helix or spiral, as in Fig. 7, and pass a

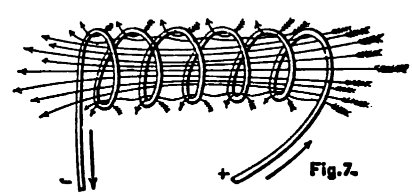


Fig. 7.

current of electricity through it, the magnetic whirls in the surrounding space are modified, and the lines of force are no longer small circles wrapping round the conducting wire. For now the lines of force of adjacent strands of the coil merge into one another, and run continuously through the helix from one end to the other. Compare this figure with Fig. 1, and the similarity in the arrangement of the lines of force is obvious. The front end of the helix acts, in fact, like the north pole of a magnet, and the further end like the south pole. If a small bar of iron be now pushed into the interior of this helix, the lines of force will run through it and magnetize it, converting it into an *electro magnet*. The magnetic "field" of such an electro magnet is shown in Fig. 8, which is reproduced from the actual figure made by iron filings. To magnetize the iron bar of the electro magnet as strongly as possible the wire should be coiled many times round, and the current should be as strong as possible. This mode of making an iron rod or bar into a powerful magnet is adopted in every dynamo-electric machine. For, as will be presently explained, very powerful magnets are required, and these magnets are most effectively made by sending the electric currents through spiral coils of wirt wound (as in Fig. 8) round the bars thae are to be made into magnets.

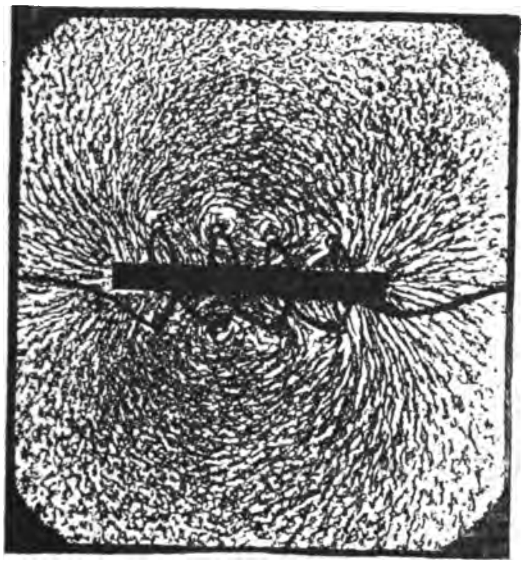


Fig. 8.

The reader will at this point probably be ready to jump to the conclusion that magnets and currents are alike surrounded by a sort of magnetic atmosphere, and such a view may help those to whom the subject is fresh to realize how such actions as we have been describing can be communicated from one magnet to another, or from a current to a magnet. Nevertheless, such a conclusion would be both premature and inaccurate. Even in the most perfect vacuum these actions still go on, and the lines of force can still be traced. It is probably more correct to conclude that these magnetic actions are propagated through space not by special magnetic atmospheres, but by there being movements and pressures and tensions in the *æther* which is believed to pervade all space as a very thin medium more attenuated than the lightest gas, and which when subjected to electro magnetic forces assumes a peculiar state, and gives rise to the actions which have been detailed in the preceding paragraph.

In the first article on this subject, we described how the electric current, or rather the wire through which it flows, possesses for the time magnetic properties, and is surrounded by lines of force. It was further shown how magnetism can be produced from electric currents, a spiral coil of wire through which a current is sent acting like a magnet.

The next point to be studied is the magnetic property of a single loop of the wire through which an electric current flows. Fig. 9 represents a single voltaic cell containing the usual plates of zinc and copper dipping into acid to generate a current in the old-fashioned way. This current flows from the zinc plate through the liquid to the copper plate, and from thence it flows round the wire ring or circuit back to the zinc plate. Here the lines of magnetic force in the surrounding space are no longer only whirls like those drawn in Figs. 4 and 6, for they react on one another and become nearly parallel where they pass through the middle of the ring. The thick arrows show the direction of the electric current, the fine arrows are the lines of magnetic force, and show the paths along which a free north pole would be urged. All the front face, where the arrow-heads are, will be like the north pole of a magnet. All the other face of the ring will be like the south pole of a magnet. Our ring resembles a flat magnet, one face all north pole the other face all south pole. Such a magnet is sometimes called a "magnetic shell."*

termed "Maxwell's Rule," is very important, because it can be so readily applied to so many cases, and will enable one so easily to think out the actual reaction in any particular case. The rule is illustrated by the sketch shown in Fig. 10, where a bar magnet has been placed with its north pole opposite the south face of the circuit of the cell. The lines of

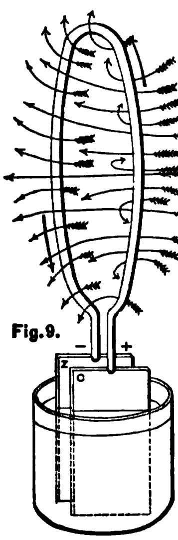


Fig. 9.

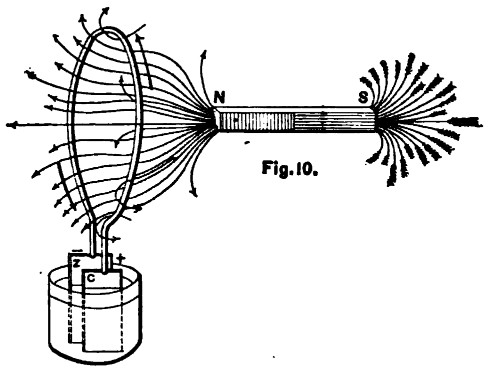


Fig. 10.

Since the circuit through which the current is flowing has these magnetic properties, it can attract other magnets or repel them according to circumstances.

If a magnet be placed near the circuit, so that its north pole N is opposite that side of the circuit which acts as a south pole, the magnet and the circuit will attract one another. The lines of force that radiate from the end of the magnet, curve round and coalesce with some of those of the circuit. It was shown by the late Professor Clerk-Maxwell that every portion of a circuit is acted upon by a force urging it in such a direction as to make it enclose within its embrace the greatest possible number of lines of force. This proposition, which has been force of the magnet are drawn into the ring and coalesce with those due to the current. According to Faraday's mode of regarding the actions in the magnetic field, there is a tendency for the lines of force to shorten themselves. This would occur if either the magnet were pulled into the circuit, or the circuit were moved up towards the magnet. Each attracts the other, and whichever of them is free to move will move in obedience to the attraction. And the motion will in either case be such as to increase the total number of lines of force that pass through the circuit. Lest it should be thought that Fig. 10 is fanciful or overdrawn, we reproduce an actual magnetic "field" made in the manner described in the preceding article. Fig. 11 is a kind of sectional view of Fig. 10, the circuit being represented merely by two circular spots or holes above and below the middle line, the current flowing towards the spectator through the lower spot, and passing in front of the figure to the upper hole where it flows down. Into this

* The rule for telling which face of the magnetic shell (or of the loop circuit) is north and which south in its magnetic properties is the following. If as you look at the circuit the current is flowing in the same apparent direction as the hands of a clock move, then the face you are looking at is a south pale. If the current flows the opposite way round, to the hands of a clock then it is the north pole face that you are looking at.

circuit the pole N is attracted, the tendency being to draw as many lines of force as possible into the embrace of the circuit.

So far as the reasoning about these mutual actions of magnets and currents is concerned, it would therefore appear that the lines of force are the really important feature to be understood and studied. All our reasons about the attractions of magnets could be equally well thought of if there were no corporeal magnets there at all, only collections of lines of force. Bars of iron and steel may be regarded as convenient conductors of the lines of force; and the poles of magnets are simply the places where the lines of force run out of the metal into the air, or *vice versa*. Electric currents also may be reasoned about, and their magnetic actions foretold quite irrespective of the copper wire that acts as a conductor: for here there are not even any poles; the lines of force or magnetic whirls are entirely outside the metal. There is an important difference, however, to be observed between the case of the lines of force of the current, and that of the lines of force of the magnet. The lines of force of the magnet *are* the magnet so far as magnetic forces are concerned; for a piece of soft iron laid along the lines of force thereby becomes a magnet and remains a magnet as long as the lines of force pass through it. But the lines of force crossing through a circuit are not the same thing as the current of electricity that flows round the circuit. You may take a loop of wire and put the poles of magnets on each side of it so that the lines of force pass through in great numbers from one face to the other, but if you have them there even for months and years the mere presence of these lines of force will not create an electric current even of the feeblest kind. There must be *motion* to induce a current of electricity to flow in a wire circuit.

Faraday's great discovery was, in fact, that when the poles of a magnet is moved into, or moved out of, a coil of wire, the motion produces, while it lasts, currents of electricity in the coil. Such currents are known as "induced currents"; and the action is called magneto-electric "induction." The momentary current produced by plunging the magnet pole into the wire coil or circuit is found to be in the opposite direction to that in which a current must be sent, if it were desired to attract the magnet pole into the coil. If the reader will look back to Fig. 10 he will see that a north magnet pole is being attracted in from behind into a circuit round which, as he views it, the current flows in an opposite sense to that in which the hands of a clock move round. Now, compare this figure with Fig. 12, which represents the generation of a mo-

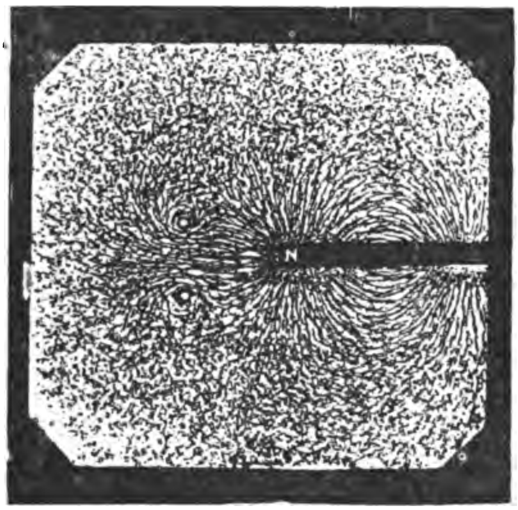


Fig. 11.

mentary induced current by the act of moving the north pole N towards a wire ring, which is in this case connected with a little detector galvanometer G. The momentary current flows round the circuit (as seen by the spectator from the

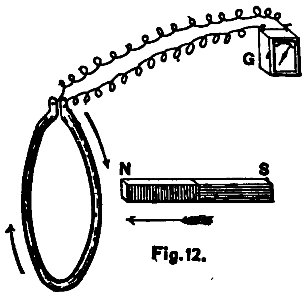


Fig. 12.

front) in the *same* sense as the movements of the hands of a clock. The induced current which results from the motion is found, then, to be in a direction exactly opposed to that of the current that would itself produce the same movement of the magnet pole. If the north pole instead of being moved towards or into the circuit were moved away from the circuit, this motion will also induce a transient current to flow round the wire, but this time the current will be in the same sense as that in Fig. 10, in the opposite sense to that in Fig. 12. Pulling the maget pole away sets up a current in the reverse direction to that set up by pushing the pole nearer. In both cases the currents only last while the motion lasts.

Now in the first article it was pointed out that the lines of force of the magnet indicate not only the direction, but the strength of the magnetic forces. The stronger the pole of the magnet is, the greater will be the *number of lines of force* that radiate from its poles. The strength of the current that flows round a circuit is also proportional to the number of lines of force which are thereby caused to pass (as in Fig. 9) through the circuit. The stronger the current, the more numerous the lines of force that thread themselves through the circuit. When a magnet is moved near a circuit near it, it is found that any alteration in the number of lines of force that cross the circuit is accompanied by the production of a current. Referring once more to Fig. 10, we will call the direction of the current round the circuit in that figure the *positive* direction; and to define this direction we may remark that if we were to view the circuit from such a point as to look along the lines of force in their own direction the direction of the current round the circuit will appear to be the same as that of the hands of a clock moving round a dial. If the magnet N S be now drawn away from the circuit so that fewer of its lines of force passed through the circuit, experiment shows the result that the current flowing in circuit will be for the moment increased in strength, the *increase* in strength being proportional to the rate of *decrease* in the number of lines of force. So, on the other hand, if the magnet were pushed up toward the circuit, the current in the circuit would be momentarily reduced in strength, the decrease in strength in the current being proportional to the rate of increase in the number of lines of force.

Similar considerations apply to the case of the simple circuit and the magnet shown in Fig. 12. In this circuit there is no current flowing so long as the magnet is at rest; but if the magnet be moved up toward the circuit so as to *increase* the number of lines of force that pass through the circuit, there will be a momentary "inverse" current induced in the circuit, and it will flow in the *negative* direction. While if the magnet were moved away the *decrease* in the number of lines of force would result in a transient "direct" current, or one flowing in the *positive* direction.

It would be possible to deduce these results from an abstract consideration of the matter from the point of view of the principle of conservation of energy. But we prefer to reserve this point until a general notion of the action of dynamo-electric machines has been given.

The following principles or generalized statements follow as a matter of the very simplest consequence from the foregoing considerations:

(*a*) To induce a current in a coil of wire by means of a magnet there must be relative motion between coil and magnet.

(*b*) Approach of a magnet to a coil or of a coil to a magnet induces currents in the opposite direction to that induced by recession.

(*c*) The stronger the magnet the stronger will be the induced currents in the coils.

(*d*) The more rapid the motion the stronger will be the momentary current induced in the coils (but the time it lasts will, of course, be shorter).

(*e*) The greater the number of turns in the coil the stronger will be the total current induced in it by the movement of the magnet.

These points are of vital importance in the action of dynamo-electric generators. It remains, however, yet to be shown how these transient and momentary induction currents can be so directed and manipulated as to be made to combine into a steady and continuous supply. To bring a magnet pole up towards a coil of wire is a process which can only last a very limited time; and its recession from the coil also cannot furnish a continuous current since it is a process of limited duration. In the earliest machines in which the principle of magneto-electric induction was applied, the currents produced were of this momentary kind, alternating in direction. Coils of wire fixed to a rotating axis were moved past the pole of the magnet. While the coil was approaching the lines of force were increasing, and a momentary inverse current was set up, which was immediately succeeded by a momentary direct current as the coil receded from the pole. Such machines on a small scale are still to be found in opticians' shops for the purpose of giving people shocks. On a large scale alternate current machines are still employed for certain purposes in electric lighting, as for example for use with the Jablochkoff candle. Large alternate-current machines have been devised by Wilde, Gramme, Siemens, De Meritens, and others, and all of these have already been described in the pages of *Engineering*. We reserve for another article the explanation of the production of direct and continuous currents in the ordinary dynamo-electric machine.

THE ANEROID PROFILE.

By FRED. W. FLOYD, E.M.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE successful use of the Aneroid Barometer on Western surveys has led to the adoption of a method of observations and computations which is not generally known, and which it will be my endeavor to describe.

The Aneroid Profile gives the relative heights between consecutive points, the horizontal distances being measured by an odometer.

The Instruments used are: the Cistern and Aneroid Barometers, Odometer, and Psychrometer.

Cistern Barometer.—The Mountain Barometers made by James Green, New York, are used. Each one is firmly fitted into a wooden case and an outer case of leather, the latter being provided with a strap so as to be carried across the back, and thus packed it is surprising what rough experiences such a delicate instrument will survive in good condition.

The least count of the vernier is .002 inch, but by interpolating .001 inch can be estimated accurately.

To be prepared for accidents an implement box containing mercury, extra cisterns, and the necessary apparatus for refilling is provided. The additional long barometer tubes are boxed by themselves.

Aneroid Barometers.—These are made to order either by Green, or by Casella, London, diameter 3 inches.

They are compensated for differences of temperature, and are intended to be so adjusted as to read uniformly inches of mercury, at a temperature of 32° Fah. at the level of the sea in 45° latitude.

The smallest division of the scale is .05 inch, but intermediate hundredths can be estimated. A movable scale of feet is added, the zero of which is at 30 inches and graduated according to Prof.

Airy's table from $-1,000$ ft. to $+18,000$ ft. (about 31 inches to 15 inches); being movable it can be adjusted for the error of the instrument as will be shown. Each instrument is provided with an attached thermometer, and is conveniently carried in a leather case hung over the shoulder by a strap.

Odometer.—This is an instrument devised for registering the number of revolutions of a wheel, after which, finding the number of revolutions in a mile on various kinds of roads (by experiment) the number of miles traveled is known.

It consists of a cylindrical brass box about 4½ inches diameter by 2½″ deep, with an axis in the center upon which a weight is hung, by means of an endless screw on the axis, a set of cog wheels attached to the weight registers the number of revolutions.

The metal box is covered with leather and strapped to two spokes of the odometer wheel, the weight remaining vertical while each revolution of the wheel and box is recorded on the dial plates of the cog wheels.

The Psychrometer—Consists of two thermometers of equal size and sensitiveness, if possible. One of these, called the web bulb, requires in temperate weather a single thickness of linen, and in freezing weather of fine gauze to be placed loosely around the bulb.

Ten minutes before commencing the observation immerse the covered bulb in water at temperature of the air; watch the wet bulb until it reaches its minimum reading; record this and the corresponding reading of the dry-bulb thermometer. In freezing weather the wet bulb should be covered with a thin film of ice; the gauze covering assists the formation of this, which should be melted off with tepid water before each observation, sufficient time being allowed for the re-formation of the film—the reading being taken at its minimum.

The readings are taken in *degrees* and *tenths* of a degree, the latter being estimated.

Each psychrometer is supplied with a wooden case and an outer one of leather.

2. FIELD PARTY.

It is understood that the travel is on mule back. The hypsometrical work is assigned to two men, the Meteorologist, and the Aneroid and Odometer Recorder, and both are under the immediate direction of the Topographer, in order that the determination of the vertical element of the survey may be best adapted to the general plan of the topography.

The Meteorologist carries in person the standard Cistern, and is intrusted with its important observations; makes all comparisons of Aneroids and also with the barometers of the United States Signal service when possible; sees that the other meteorological instruments are in proper condition, and prepares the final record ready for computation.

The Aneroid and Odometer Recorder has charge of the instruments indicated, and records the observations as hereafter explained. For convenience he rides the odometer mule.

OBSERVATIONS.

The initial point is the rendezvous camp, the altitude of which if not already known by spirit leveling, as when it is on a railroad, is determined from a series of hourly reading of the cistern barometer and other instruments, for as long a period as the party remains in camp, or if that is not possible, readings at 7 A.M., 2 and 9 P.M., that they may be referred by means of synchronous observations to some Signal Service Station whose elevation is known.

When in camp for one or more days, however, hourly observations should be taken day and night, for the purpose of forming tables of horary oscillation and for obtaining good aneroid errors.

Before leaving camp the error of the aneroid is determined by comparison with the cistern barometer (readings reduced to 32° Fah.) If large it is corrected as nearly as possible by means of the adjusting screw at the back of the instrument, and again compared to obtain the exact error; the zero of the movable scale is then set to the right or left of 30 inches, by an amount in inches equal to this error of the aneroid—if *too low* it is set to left of 30 inches, if *too high* to the right of 30 inches by amount of the error in inches.

At each meander station made by the Topographer, including always the stations upon entering and leaving camp, the Odometer Recorder enters the time of day, aneroid, thermometer, and odometer readings, and the Topographer locates the point either by angles between well-fixed points, or from his meander bearings and the measured distances.

The aneroid is read in feet and inches; in feet for the convenience of the Topographer in making his field sketches, and in inches for the accurate determination of altitudes by computation; the reading in feet also serves to correct a mistake which sometimes happens—that of recording the change of inches incorrectly; it should be held vertical while being read as the weight of the instrument affects the indications and it must therefor always be read in the same position. At each station then, the odometer gives the distance traveled and the aneroid the difference in level between it and the preceding station; when camp is made at night the aneroid is compared with the cistern barometer, which indicates any change of error in the former. At important points of the meander, springs, divides, passes, &c. the cistern barometer is also read, and these comparisons serve as checks in distributing the error of the aneroid for the day.

The observations, giving the data from which the profile for the day is computed, are recorded on the following form:

FORM I.

DATE: SEPTEMBER 14, 1878. PARTY: 1; SECTION, UTAH; ———, RECORDER.
FROM CAMP NO. 24 AT CHICO, CAL., TO CAMP NO. 25 AT FOREST RAUCH, CAL.

Station.	Hour.	Aneroid. No. 6. Reading.	Temperature.	Cist. bar.* No. 1735. Reading.	Att'd T.	Error of Aneroid.	Station.	Odometer. Reading.	Pr. mile.	Miles.	Aneroid in feet.	Zero set at inches.	Remarks.
	A.M.												
Camp No. 24	7:30	29.64	58.5	29.798	53.8	—.084	Camp No. 24	000	426		250	29.92	Chico, Butte Co.
1	8:00	29.64	62.0	..	..	..	1	447	.	1.049	250	..	
2	8:20	29.64	65.0	..	..	..	2	606	.	.373	250	..	
3	9:20	29.58	67.5	..	..	..	3	1772	.	2.737	300	..	Foot-hills.
4	9:40	29.43	70.0	..	..	..	4	2116	.	.807	425	..	
5	10:10	29.13	74.0	..	..	..	5	2644	.	1.240	700	..	
6	10:45	28.80	75.5	..	..	..	6	3148	.	1.268	1000	..	Hog Spring.
7	11:10	28.66	76.0	..	..	..	7	3545	.	.932	1125	..	
8	11:45	28.45	76.0	..	..	..	8	4029	.	1.136	1325	..	
	P.M.												
9	12:10	28.27	78.0	28.448	78.5	..	9	4478	.	1.054	1500	..	
10	12:30	28.22	78.0	..	..	..	10	4773	.	.692	1525	..	10-mile Ho'se
11	1:15	28.05	78.0	..	..	..	11	5055	.	.662	1700	..	
12	1:40	27.80	78.5	..	..	..	12	5432	.	.885	1900	..	
13	2:00	27.83	78.0	..	..	..	13	5582	.	.352	1875	..	
14	2:30	27.84	77.8	..	..	..	14	6001	.	.984	1875	..	
15	2:50	27.70	77.0	..	..	..	15	6296	.	.692	2000	..	Toll-gate.
16	3:30	27.40	75.3	..	..	..	16	6772	.	1.117	2300	..	
Camp No. 25	4:00	27.48	74.0	27.670	72.6	..	Camp No. 25	7219	.	1.049	2225	.	Forest Ra'ch, Butte Co.
										17.029			

* Error of No. 1735+.006.

COMPUTATIONS.

Cistern Barometer Stations:—These embrace isolated points, such as Mountain Peaks, Divides, Passes, Towns, &c., and the camps between which the aneroid profile is run.

(*a*) All hourly series are examined by plotting the observations at 32° Fah., and erratic observations corrected by interpolation reduced to level by Col. Williamson's method, and tables of horary corrections formed for the reduction of isolated observations and for the aneroid work.

(*b*) The observations taken at the

permanent reference stations are plotted and corrected; these stations are then referred to each other by the mean of the series and their relative and absolute heights determined, provided these have not already been determined by lines of level.

(*c*) The altitudes of camps and stations where cistern barometers are read for several days are computed by referring the observations to corresponding observations at the reference stations by the mean of the series, and of all camps and other points where isolated observations are taken by daily means, the readings being corrected for horary oscillation. If camp is made for one night only the observations are computed in pairs (9 P. M. and 7 A. M. readings) with horary correction.

In order that the successive steps in the computations may be fully understood, it is thought best to give the data and reduction work necessary for a complete profile, including reference and camp stations.

Form II. gives the Reduction to Level of the observations at Prattville. Only that portion of the horary curve has been deduced, which was necessary for the hours during which the aneroid profile was run, viz., 6 A. M. to 9 P. M. (See next column.)

Having obtained the horary curve the height of barometer from daily means is used in determining the altitude of Prattville, referring to synchronous observations at the Signal office at Red Bluff, Cal., the altitude of which has been determined by R. R. levels.

For convenience the form herewith has been adopted (see page 277).

h and H are the heights of the barometer at the lower and upper stations reduced to 32° Fah., *t*, *t'* the temperatures of the air at the two stations, and *a*, *a'* the relative humidities at each point—the approximate latitude is also given.

The hypsometrical tables representing the full formula of Plantamour, found in the appendix of Lt. Col. Williamson's Treatise on the Barometer; Professional Papers, Corps of Engineers, No. 15 and represented by tables D are used.

The altitude of the camp at Chico, *from* which the profile is run, has been computed from two sets of observations and the mean of the results taken.

FORM II.—STATION: PRATTVILLE, PLUMAS CO., CAL. BAROMETER AT 32° FAH. DATE, OCT. 4 TO OCT. 13, 1878.

Day.	7 A.M.	8 A.M.	9 A.M.	10 A.M	11 A.M	12 M.	1 P.M.	2 P.M.	3 P.M.	4 P.M.	5 P.M.	6 P.M.	7 P.M.	8 P.M	9 P.M.	6 A.M.	Daily mean.
October 4th	25.622	25.626	25.632	25.618	25.607	25.588	25.577	25.567	25.552	25.554	25.556	25.564	25.572	25.596	25.615	25.659	
" 5th	.660	.673	.664	.645	.634	.610	.601	.593	.578	.574	.578	.592	.606	.614	.628	.665	
" 6th	.673	.678	.675	.651	.648	.621	.604	.598	.584	.581	.578	.581	.597	.608	.620	.620	
" 7th	.625	.622	.619	.603	.585	.555	.524	.525	.503	.504	.505	.504	.517	.521	.527	.546	
" 8th	.550	.557	.556	.544	.537	.519	.498	.483	.470	.465	.467	.463	.470	.477	.474	.410	
" 9th	.417	.426	.423	.406	.410	.399	.396	.401	.455	.436	.434	.440	.468	.484	.503	.577	
" 10th	.587	.608	.628	.618	.608	.592	.574	.563	.554	.551	.548	.551	.569	.570	.585	.562	
" 11th	.581	.583	.573	.554	.532	.508	.483	.467	.463	.456	.457	471	.473	.465	.464	481	
" 12th	.483	.504	510	.494	.503	.479	.480	.492	.484	.479	.479	.482	.464	*.468	.472	.496	*Observation not taken.
" 13th	25.496																
Sum	5198	5277	5280	5133	5064	4871	4737	4689	4643	4600	4602	4648	4736	4803	4888	5016	
Reduction to level ..	.000	+.005	+.010	+.016	+.021	+.026	+.031	+.037	+.042	+.047	+.052	+.058	+.063	+.068	+.073	+.121	
Sum reduced to level	5198	5282	5290	5149	5085	4897	4768	4726	4685	4647	4654	4706	4799	4871	4961	5137	
Mean	25.578	.587	.588	.572	.565	.544	.530	525	.521	.516	.517	.523	.533	.541	.551	.571	
Grand mean	25.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	
Horary correction ..	−.030	−.039	−.040	−.024	−.017	+.004	+.018	+.023	+.027	+.032	+.031	+.025	+.015	+.007	−.008	−.023	

FORM III.

Names of Tables, &c.	Computation.	Computation.	Computation.	Computation.
Date, 1878	Oct. 4 to 12.	Aug. 6 to 9.	Sept. 11 to 14.	Sept. 15 and 15.
No. of Synchronous Obs.	Daily Means.	Daily Means.	Daily Means.	2.
Lower Station	Red Bluff.	Camp 1 (24) Chico, Cal.	Camp 24 (1) Chico, Cal.	Red Bluff.
Upper Station	36, Prattville.	Red Bluff.	Red Bluff.	Camp 25 Forest Ranch.
Bar at 32° $h=$	29.552	29.645	29.722	29.484
Bar at 32° H=	25 247	29.477	29.555	27.548
Temperature $t_1=$	69.2	75 2	69.6	67.1
Temperature $t'=$	48.5	83.6	75.6	44.7
$t+t'=$	117.7	158 8	145.2	111.8
Humidity $a=$	.470	.447	.428	.494
Humidity $a'=$	.643	.364	.405	.481
$a+a'=$	1.113	.811	.833	.975
Latitude =	40° 20′	40 00	40 00	40 00
D_I (h) =	28416.1	28498.4	28566.5	28355.7
D_I (H)=	24596.9	28349.4	28418 7	26574.5
1st Approx.	3819.2	149.0	147.8	1781.2
D_{II} =	208.9	14.4	12.2	86.7
2d Approx.	4028.1	163.4	160.0	1867.9
D_{III} =	1.8	0.0	0.0	0 9
D_{IV} =	10.9	0.4	0.4	4.9
D_V =	0.1	0.0	0.0	0.2
3d Approx.	4040.9	163.8	160.4	1873.9
D_{VI} =	41.0	2.0	2.0	19.0
D_{VII}=	13.7	1.4	1.1	5.7
Correct for $(a+a')$=	15.2	1.1	0.9	5.5
Diff. of Altitude =	4056.1	164.9	161.3	1879.4
Alt. of Reference Station=	338.0	338 0	348.0	338.0
Altitude of Station =	4394.1	173.1	176.7	2217.4
Remarks	Adopt for Chico, 174.9.			

The altitude of Camp 25, *to* which the profile is run, was obtained from the mean of 9 P. M. and 7 A. M. readings of the C.B., reduced to 32°, and the horary correction applied.

Aneroid Barometer Stations:—Having determined the altitude of camps 24 and 25, the profile between can be computed, the observations as shown in Form I., are transcribed on Form IV., in columns 1, 2, 3, 4, 10 and 20 (see page 278).

The readings of the C.B. are then reduced to 32° Fah., and corrected for instrumental error, and the correction for the error of the aneroid determined.

On leaving camp at 7.30 A. M. the error was −0.084 ins., at 12.30 P. M. when the next comparison was made it was −0.095; a mean of the two is therefore assumed for that portion of the day and a correction of +0.090 applied.

On entering camp at 4 P. M. the error was −0.076, and the mean of this and the previous comparison gives −0.086, thus indicating that the aneroid had maintained a nearly constant error during the day. The horary curve as previously determined at Prattville is next applied, interpolating where necessary, to reduce the observations to the mean of the day. The algebraic sum of these corrections for each station gives the "total correction" to be applied to the respective readings. Each station is referred to the preceding one by means of Col.

FORM IV.—DATE: SEPTEMBER 14, 1878. CAMP NO. 24 TO NO. 25.

Station.	Hour.	Aneroid No. 6. Reading.	Cist. Bar. No. 1785. Error +.006. Reading.	Att. Th.	Bar. at 32°	Correct for error of Aneroid.	Correct for Hor. Oscil.	Total correction.	Correct readings.	Temperature.	t+t'	$D_1 (h-H)$	1st Approx. diff. of altitude.	D_{11}	2d Approx. diff. of altitude.	Altitude.	Distribution of error.	Altitude above sea level.	Diff. of altitude between stations.	Distance in miles.	Remarks.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Camp No. 24	A.M. 7:30	29.64	29.798	53.8	29.724	+.090	−.034	+.056	29.696	55.5	146°	28543.5	Altitude by Cis. Bar.			174.9	..	174.9	..	..	Chico, Butte Co., Cal.
1	8:00	29.64	..	..	..	+.090	−.039	+.051	.691	62.0	..	28539.1	+ 4.4	0.2	+ 4.6	179.5	−3.2	176.3	1.4	1.049	Chico P. O.
2	8:20	29.64	..	..	..	+.090	−.039	+.051	.691	65.0	..	28539.1	0.0	0.0	0.0	179.5	6.4	173.1	3.2	.373	
3	9:20	29.58	..	..	..	+.090	−.035	+.055	.635	67.5	..	28489.6	+ 49.5	4.7	+ 54.2	233.7	9.6	224.1	51.0	2.737	Foot-hills.
4	9:40	29.43	..	..	..	+.090	−.030	+.060	.490	70.0	..	28361.0	+128.6	11.7	+140.3	374.0	12.8	361.2	137.1	.807	
5	10:10	29.13	..	..	..	+.090	−.023	+.067	29.197	74.0	..	28099.0	+262.0	23.8	+285.8	659.8	16.0	643.8	282.6	1.240	
6	10:45	28.80	..	..	..	+.090	−.019	+.071	28.871	75.5	..	27804.7	+294.3	26.8	+321.1	980.9	19.2	961.7	317.9	1.268	Hog Spring.
7	11:10	28.66	..	...	..	+.090	−.014	+.076	.736	76.0	..	27681.8	+122.9	11.2	+134.1	1115.0	22.4	1092.6	130.9	.932	
8	11:45	28.45	..	..	..	+.090	−.002	+.088	.538	76.0	..	27500.5	+181.3	16.5	+197.8	1312.8	25.6	1287.2	194.6	1.186	
9	P.M. 12:10	28.27	..	..	..	+.090	+.007	+.097	.367	78.0	..	27342.7	+157.8	14.4	+172.2	1485.0	28.8	1456.2	169.0	1.054	
10	12:30	28.22	28.448	78.5	28.315	+.090	+.012	+.102	.322	78.0	..	27301.1	+ 41.6	3.8	+ 45.4	1530.4	32.0	1498.4	42.2	.692	10-mile House.
11	1:15	28.05	..	..	..	+.086	+.019	+.105	28.155	78.0	..	27146.0	+155.1	14.1	+169.2	1699.6	35.2	1664.4	166.0	.662	
12	1:40	27.80	..	..	..	+.086	+.021	+.107	27.907	78.5	..	26914.2	+231.8	21.1	+252.9	1952.5	38.4	1914.1	249.7	.885	
13	2:00	27.83	..	..	..	+.086	+.023	+.109	.939	78.0	..	26944.3	− 30.1	2.7	− 32.8	1919.7	41.5	1878.2	35.9	.852	
14	2:30	27.84	..	..	..	+.086	+.025	+.111	.951	77.8	..	26955.5	− 11.2	1.0	− 12.2	1907.5	44.6	1862.9	15.3	.984	
15	2:50	27.70	..	..	..	+.086	+.026	+.112	.812	77.0	..	26824.7	+130.8	11.9	+142.7	2050.2	47.7	2002.5	139.6	.692	Toll-gate.
16	3:30	27.40	..	..	..	+.086	+.030	+.116	.516	75.3	..	26544.0	+280.7	25.6	+306.3	2356.5	50.8	2305.7	308.2	1.117	
Camp No. 25	4:00	27.48	27.670	72.6	27.556	+.086	+.032	+.118	27.598	74.0	..	26622.1	− 78.1	7.1	− 85.2	2271.3	53.9	2217.4	88.3	1.049	For'st Rauch, Cal.
																				17.029	

Altitude of Camp No. 2 by Cis. Bar. 2217.4
Error in Aneroid Profile........ +53.9 ft.

Williamson's Tables D, for computing differences of altitude, and thus the first approximate difference of altitude between stations is obtained. The temperature term is next considered; instead of $t+t'$ being taken separately for each pair of stations, the operation is shortened by taking twice the average of the several temperature readings during the meander. These corrections (Col. 14) are obtained from tables giving values of the factor $\frac{t+t'-64}{900}$, and is different from the temperature term used in connection with corrections for humidity.

Beginning at camp, the successive differences of altitude between the meander stations is then added, each to the altitude of the station preceding, and the profile carried over to the next camp, by successive steps. The difference between this altitude and that of the computed cistern altitude is the error to be distributed throughout the profile, to make it *close;* in distributing the error it is assumed that the non-periodic* oscillation is uniform during the few hours in which the profile is run, and that this error in the altitude of each station is directly proportional to the time. Usually it is sufficient to divide the error equally between the various stations, as has been done in this case.

* As opposed to the periodic or horary oscillation.

The method herein described for obtaining Aneroid Profiles has been in use by the War Department Surveys, under Capt. Wheeler, Corps of Engineers, since 1874, and has become a distinctive feature of that work. When the meander is from fifteen to twenty miles a day the running of the usual line of level is out of the question; formerly the cistern barometer was entirely relied upon, but the time occupied in a single reading when the instrument has to be screwed up, inverted and packed after each reading, rendered only a few observations possible.

The results now obtained have proved entirely satisfactory for the scale upon which the topographical maps are constructed (1 inch to 8 miles or 1 : 506,880), and indicate that the Aneroid Barometer used in connection with the Mercurial is the most practicable instrument in surveying for preliminary routes for wagon or railroad, and for rapid contouring, and is an indispensable, and *not*, as is frequently believed, an unreliable instrument to the engineer.

REPORT ON THE CASTOR-OIL GAS WORKS OF JEYPORE, INDIA.

By MAJOR S. S. JACOB, B.S.C., Assoc. Inst. C.E., Exec. Eng.

From Professional Papers on Indian Engineering, Roorkee, April, 1881.

In this paper the author first gives general results, showing the cost of the construction of the Jeypore gasworks, and of the manufacture of gas made from castor oil, from Sept. 1, 1879, to Sept. 1, 1880, and then supplements his Report with a statement of details prepared by the resident superintendent, Mr. Tellery, of whose management he speaks in terms of warm eulogy.

The gasworks, including apparatus, pipes, lamp posts, &c., were built by contract for the sum of 317,822 rupees, and produced during the year 1879-80 1,184,644 cubic feet of gas, at a cost for material used of 23r. 2a. 5p. per 1,000 cubic feet during the first half-year, and of 18r. 1a. 8p. per 1,000 cubic feet during the second half-year; but if the expenses of the establishment and salaries (7387 rupees for the whole year) are included, these figures become respectively 29r. 7a. 8p. and 26r. 15a. 7p. per 1,000 cubic feet.*

The average daily number of jets for the first six months was four hundred and seven, and for the last six (the summer) months three hundred and seventy-five, and each jet is stated to consume 1¾ cubic foot per hour, the cost of each jet per night of six hours having been 6¾d.

* These figures are exactly as given in the report. In this abstract where rupees have been converted into English money the nominal exchange of 1 rupee =2 shillings has been adopted.

An oil gas-burner consuming 1 cubic foot per hour will give as much light as a coal gas-burner consuming 2½ cubic feet per hour. Castor oil is chiefly used; but this is supplemented with other oils, such as poppy, til, and rape oil, when procurable at more favorable rates. Mr. Tellery has taken much pains to increase the cultivation of the castor plant, and personally superintended the sowing of about 300 acres in the neighborhood of Jeypore.

One maund (82 lbs.) of castor oil produces 750 cubic feet of gas of 26½-candle power, or 1,000 cubic feet of 18½-candle power, or 1,250 cubic feet of 9-candle power.* The other oils produce 610 cubic feet of the first, 762 cubic feet of the second, and 914 cubic feet of the third quality of gas, so that the gas made from castor oil is the cheapest, although it costs £1 3s. 6d. per maund and the other oils only £1 per maund.

The apparatus (patented by Professor Herzel of Leipzig, Germany) originally consisted of two sets of six retorts each in a separate oven, and oil gas was made in three retorts, whilst water was decomposed and hydrogen gas produced in the other three retorts. But Mr. Tellery soon found it advisable to dispense with the hydrogen retorts, which increased the cost of wear and tear; he also decided to set each retort separately, and now works two retorts at a time, which generate gas on an average during two hundred and eighteen hours monthly, producing 98,720 cubic feet, at a cost for wear and tear, fuel, stokers, and purification (exclusive of the cost of oil), of 4r. 4a. 4¾p. per 1,000 cubic feet, which Mr. Tellery believes might be reduced to 2r. 9a. 5¾p., if the consumption should increase to 260,000 cubic feet per month.

From 33 to 40 per cent. of oil are extracted from the castor seed, the shells being first broken off in a crusher, and separated by hand from the seed, which is then crushed to a paste, heated in pans, and, lastly, packed in horsehair bags and pressed hot in hydraulic oil presses, each of which produce about 7½ maunds (615 lbs.) weight of oil per diem.

The process of manufacturing the gas is as follows:

The retorts have first to be heated from six to eight hours, till they are sufficiently hot to decompose the oil and generate gas favorably. Then the oil is passed from above into the retort through a siphon, taking care that no more oil shall enter than the retort can instantly decompose, as otherwise it would distil over as vapor, and very little useful gas would be generated; but if too little oil enters the retort, then the gas, although more in quantity, is of a poorer quality, which also must be guarded against. A good deal of tar and ammoniacal liquor is deposited in a hydraulic cylinder after the gas first leaves the retorts, and more on its passage through a square cooling vessel, after which the gas passes into two coke towers, and from thence into purifiers filled with dry lime, sulphate of iron and copper, and sheep's wool saturated in naphtha and sawdust, which clears it of its carbonic acid; and from here it passes in a purified state into the gasholder.

It is proposed to utilize the tar (for which there is not sufficient sale) by burning it for lampblack.

Some buildings have been lighted temporarily by means of portable wrought-iron tanks, into which the gas is compressed at a pressure of about 50 lbs. to the square inch, and conveyed by cart to the spot where it is stored in small gas-holders. On one occasion, after being so stored for nine months, the gas burned as bright and clear as when first made.

* Respectively 21,000, 28,000, and 35,000 cubic feet per ton of oil.

In one form of secondary battery M. J. Rousse uses for the negative electrode a sheet of palladium, which during the electrolysis absorbs more than 900 times its volume of hydrogen; at the positive pole he uses a sheet of lead; the electrolyte being a 10 per cent. solution of sulphuric acid. Another form giving good results is produced by making the negative electrode of thin sheet iron, which absorbs more than 200 times its volume of hydrogen when electrolyzed in a 50 per cent. solution of sulphate of ammonia. The positive pole is formed of a sheet of lead covered with a layer of litharge. Platinum and palladium are too dear, unless used to platinumize or palladiumize other substances for electrodes.

THE THEORY AND PRACTICE OF VENTILATING COAL MINES.

By W. FAIRLEY, M.E., F.S.S.

II.

THE EFFECT OF SPLITTING THE AIR.

32. In this place it seems desirable to explain what is meant by "splitting the air." Originally it was the usual custom to circulate the air through a mine in one undivided current, down one shaft, around the workings, and up the other shaft, and this plan is still in use in some simple cases. When this one current is divided in the mine into two or more currents, which unite again at or before reaching the upcast, it is said to be split. Splits may be of equal or unequal length and area. The expression "two equal splits" means that the original one current is divided into two currents, each of half the length, but both with the same area as the original one. It must be noted that the phrase "equal splits" is more a mathematical than a practical one, for it may be safely said that to split a current into two, three, or more equal dimensions is never done practically; it can, however, in some cases be done nearly. After this explanation it will be understood that theoretical splitting will always show a somewhat better result than practical splitting, because, owing to the varied circumstances of the mine, the air cannot always be exactly equally divided, and in practice, as a rule, the aggregate length of the various splits will be somewhat longer than the original one current; or the splitting will take place too far in-bye, or reunite again too far away from the bottom of the upcast. No one understood this better than the late Mr. Atkinson; hence he says:—"Every principal split of air should commence as near as possible to the bottom of the downcast shaft, and should have a distinct airway to return in."

In the calculations which will be brought forward in this chapter with reference to splitting, it will be on the assumption that the splits take place at the bottom of the downcast, and re-unite at the bottom of the upcast—in fact that the splits are equal. Unequal splitting will be taken into consideration in the next section.

Suppose the original aircourse of the mine to measure 40 ft. area (a), and 120,000 rubbing surface (s); by splitting into two equal currents we should get two airways each 40 ft. area (a) and 60,000 rubbing surface; by splitting into three currents we should have three airways, each 40 ft. area and 40,000 rubbing surface; the area, after splitting, being two or three times that of the original airway, according to the number of splits, but the total rubbing surface remaining the same throughout.

It is necessary here to explain further that when this original one current is divided into two equal splits, they may be considered as one current with double the area, but with the same rubbing surface. When divided into three equal splits, these three divisions may be considered as one airway of treble the original area, but with the same rubbing surface, in fact, as tabulated below:

		a.	s.
Original current		40	120,000
Two equal splits	1...	40	60,000
	1...	40	60,000
Equal one current		80	120,000
Three equal splits	1...	40	40,000
	1...	40	40,000
	1...	40	40,000
Equal one current		120	120,000

This will be proved arithmetically further on.

33. The benefit derived from splitting depends very much upon the relative rubbing surfaces and the areas of the shafts, as compared with those of the mine, and unless the friction due to the shafts be taken into account when the effect of splitting is calculated, the result will be fallacious.

Were it not for the resistance of the shafts, which, of course, varies with the quantity of air passing, the result of splitting would be more easily calculated.

34. It may perhaps be better, for the sake of the student, that we should in the first place consider the effect of splitting without taking into account the shaft resistances, so that he may acquaint himself gradually with the process of calculation, and eventually see the difference of the two results.

35. The following example is given for calculation: the quantity of air passing round a mine in one current before splitting is 10,000 cubic feet per minute; the area of the aircourse is 20 ft., and the rubbing surface is 24,000, what quantity will circulate when the current is split into 2, 3, 4, 5, 6, and 10 equal divisions, the pressure remaining the same?

In the first place the pressure (p) for the one current may be found by the rule $\frac{ksv^2}{a}$, this will be 6.51 lbs. The effect of splitting into 2, 3, &c., divisions, as has been explained in paragraph 31, is to double, treble, &c., the area, without altering the rubbing surface, and as the quantity is obtained by the rule $\sqrt{\frac{pa}{ks}} \times a$, we use this to find the quantities with the various splits in operation; but as p, k, and s are the same in all these instances, the formula will be reduced to this simple rule $\sqrt{a}\times a$, and the relative quantities will be according to the square root of the area multiplied by the area, as tabulated below:

No. of splits.	s.	a.	$q=\sqrt{\frac{pa}{ks}}\times a$.	$p=\frac{ksv^2}{a}$
1	24,000	20	10,000	6.51
2	24,000	40	28,284	6.51
3	24,000	60	61,961	6.51
4	24,000	80	80,000	6.51
5	24,000	100	111,808	6.51
6	24,000	120	146,969	6.51
10	24,000	200	316,228	6.51

or the question may be worked out without reference to the actual dimensions of the areas and rubbing surfaces in each case, further than considering the areas to vary as 1, 2, 3, 4, &c. Then the quantities that will pass will be most simply found thus:—If $\sqrt{1}\times 1 : 10{,}000 :: \sqrt{2}\times 2 : =28{,}284$, the quantity with two splits, and if $\sqrt{1}\times 1 : 10{,}000 :: \sqrt{10}\times 10 : = 316{,}228$, the quantity with ten splits as above.

An example similar to this is given further on, showing what the result will be after taking into account the shaft resistances.

36. If the power is to remain the same, instead of the pressure, and the original aircourse passing 10,000 cubic feet per minute, the quantity that will pass in each case of 2, 3, 4, 5, 6, and 10 equal splits will be simply in direct proportion to the area:—1, 10,000; 2, 20,000; 3, 30,000; 4, 40,000; 5, 50,000; 6, 60,000; 10, 100,000. The rule to find the quantity when the power (u) is given being $\sqrt[3]{\frac{u}{ks}}\times a$, but k, s and u being the same in the case of all the splits, these may be canceled, and the quantities will be directly according to the area as stated above.

37. There is a great difference between splitting the air and adding an additional aircourse of the same length and area as the original one; thus, in dividing one current into two equal splits, we get an increase from 10,000 to 20,000 with the same power, but by adding an additional aircourse the increase will only be from 10,000 to 15,874; this may be worked out as follows:

Take a to equal 36 and s to equal 18,000, then the power is found by the formula $\frac{ksv^2q}{a}=8371.4$ foot pounds $= u$. With the additional aircourse "a" and "s" will be doubled, and as the velocity is got by $\sqrt[3]{\frac{u}{ks}}$, we use these figures $\sqrt[3]{\frac{8371.4}{.0000000217\times 36000}}\times 72$, to get the quantity which is equal to 15,874 cubic feet per minute, or the quantity is according to the reciprocal of the cube root of the rubbing surface multiplied by the area; as both s and a are in the proportion of one to two we say,

If $\sqrt[3]{\frac{1}{1}}\times 1 : 10{,}000 :: \sqrt[3]{\frac{1}{2}}\times 2 : =15{,}874$, the same as above.

38. So far, we have not taken into account the shaft resistances, but in the next example we will do so.

If there are 10,000 cubic feet of air passing through a mine in one current, the resistances of the shafts at that time being equal to the resistance of the mine, what extra quantity of air will pass through the mine by adding an additional aircourse, same length and area as the original one, the power remaining the same?

In order to make the resistance of the shafts and mine equal, take the area and rubbing surface of each the same. With the addition of another aircourse, both the area and rubbing surfaces in the mine are doubled. Proceeding in this way, the results have been obtained as below:

Divisions of air.		q.	a.	s.	p.	u.
1	Shafts..	10,000	36	18,000	.83714	8371.4
	Mine...	10,000	36	18,000	.83714	8371.4
	Total...			36,000		16742 8
2	Shafts..	11,694	36	18,000	1.1455	13394.8
	Mine...	11,694	72	36,000	.28662	3348.5
	Total...					16742.8

Having taken the area of the shaft and mine at 36, and rubbing surface of each at 18,000 with one current, we find that the power required to pass 10,000 ft. through the mine and shafts amounts to 16742.8 foot pounds (u). The value of p is obtained by

$$\frac{\left(\frac{q}{a}\right)^2 \times s \times k,}{a} \text{ and of } u \text{ by } qp.$$

Now, in order to apportion the power that will be used up by the shaft and mine after making the additional aircourse, we put the two aircourses of the mine into one, the dimensions of which will be 72 a and 36,000 s; and use the formula given in paragraph 30, viz., $\left(\frac{1}{a}\right)^3$. By this we find 13394.3 units are required to pass the same quantity of 11,694 cubic feet per minute through the shafts that 3348.5 units will pass through the mine. Or, the power used in the shafts will be found thus:

$$\frac{16742.8 \times 18000 \times \left(\frac{1}{36}\right)^3}{18000 \times \left(\frac{1}{36}\right)^3 + 36000 \times \left(\frac{1}{72}\right)^3} = 13394.3$$

that of the mine thus:

$$\frac{16742.8 \times 36000 \times \left(\frac{1}{72}\right)^3}{18000 \times \left(\frac{1}{36}\right)^3 + 36000 \quad \left(\frac{1}{72}\right)^3} = 3348.5$$

Total.................. 16742.8

39. If the resistances of the shafts are half those of the mine when there are five equal splits, and there are 10,000 ft. of air passing in one current before being split at all, the quantities that will pass through the mine with 2, 3, 4, 5, 6, and 10 equal splits are stated in the table on page 284, the same ventilating pressure being in operation.

In this table it is shown that, with six equal splits and area taken at 120, and rubbing surface 24,000 the pressure required to pass 107,863 ft. through the mine is 3.50645. Here we have taken the six equal splits as one current, and to show that this one current would be equal to the six splits taken collectively we give the following figures:

	s.	a.	p.	q.
6 equal splits =	4000	20	3.50645	17977⅙
	4000	20		17977⅙
	4000	20		17977⅙
	4000	20		17977⅙
	4000	20		17977⅙
	4000	20		17977⅙

All the splits are reckoned to be divided at the bottom of the downcast, and to re-unite at the bottom of the upcast. They are therefore all to be considered as subject to one common pressure; taking this for each at 3.50645, and using the formula $\sqrt[2]{\frac{pa}{ks}} \times a$, we shall find that each separate split will pass 17977⅙ ft., and the total quantity in the six splits will be 107,863 ft., and therefore one current having $s = 24{,}000$ and $a = 120$ is equal to six divisions taken together, each of them having $s = 4000$ and $a = 20$.

Here a of shafts has been made to equal 100 and $s = 12{,}000$, and of mine when there are five splits $a = 100$, $s = 24{,}000$, for by these conditions we shall

Division of the current.	Relatively.			Actual.			
	s.	*a*.	$p=\frac{s\left(\frac{1}{a}\right)^2}{a}$	*s*.	*a*.	*p*.	$q=\sqrt[2]{\frac{pa}{ks}}\times a$
	1.	2.	3.	4.	5.	6.	7.
1 { Shafts......	1	10	.001	12,000	100	.02604	10,000
1 { Mine.......	2	2	.25	24,000	20	6.51	10,000
			.251			6.53604	
2 { Shafts......	1	10	.001	12,000	100	.20267	27,898
2 { Mine.......	2	4	.03125	24,000	40	6.33337	27,898
			.03225			6.53604	
3 { Shafts......	1	10	.001	12,000	100	.63710	49,463
3 { Mine.......	2	6	.009259	24,000	60	5.89894	49,463
			.010259			6.53604	
4 { Shafts......	1	10	.001	12,000	100	1.33219	71,526
4 { Mine.......	2	8	.00390625	24,000	80	5.20385	71,526
			.00490625			6.53604	
5 { Shafts......	1	10	.001	12,000	100	2.17868	91,469
5 { Mine.......	2	10	.002	24,000	100	4.35736	91,469
			.003			6.53604	
6 { Shafts......	1	10	.001	12,000	100	3.02959	107,863
6 { Mine.......	2	12	.0011574	24,000	120	3.50645	107,863
			.0021574			6.53604	
10 { Shafts......	1	10	.001	12,000	100	5.22883	141,704
10 { Mine.......	2	20	.00025	24,000	200	1.30721	141,704
			.00125			6.53604	

have the resistances of the shafts half those of the mine when there are five equal splits, as desired in the question. In explanation of the figures given under columns *s*, *a*, and *p* "relatively," it may be said that the rubbing surfaces of the shafts and mine are in the proportion of 1 and 2, both in the case of the one current, and all the splits and the areas are in the proportions given in the second column; the third column shows the relative pressure required to pass equal quantities through airways having the conditions given in columns 1 and 2. With reference to the figures in column 6, they are obtained by apportioning them according to their relative pressures in the third column; thus, the pressure per foot at work in producing the ventilation is 6.53604 lbs., when 10,000 ft. pass in the one current, the result being got at by working out both for the shafts and mine the rule

$$\frac{\left(\frac{q}{a}\right)^2\times s\times k}{a}$$

; and we say, for example, in the case of two splits, if .03225 give 6.53604, what will .001 give? and, if .03225 give 6.53604, what will .03125 give? by which we obtain .20267, the pressure required in the shafts, and 6.33337, the pressure required for an equal quantity of air in the mine; and so for the other splits. The quantity in the seventh column is obtained by $\sqrt[2]{\frac{pa}{ks}}\times a$; or the result may be determined more directly by using the relative pressures obtained in column 3; the quantities will be according to the square root of these, thus:

$$\text{With 2 splits}=\frac{\sqrt{\frac{.001}{.03225}}\times 10000}{\sqrt{\frac{.001}{.251}}}=27898.$$

$$\text{With 3 splits}=\frac{\sqrt{\frac{.001}{.010259}}\times 10000}{\sqrt{\frac{.001}{.251}}}=49463.$$

$$\text{With 4 splits} = \frac{\sqrt{\frac{.001}{.00490625}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 71526.$$

$$\text{With 5 splits} = \frac{\sqrt{\frac{.001}{.003}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 91469.$$

$$\text{With 6 splits} = \frac{\sqrt{\frac{.001}{.0021574}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 107863.$$

$$\text{With 10 splits} = \frac{\sqrt{\frac{.001}{.00125}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 141704.$$

40. Considering the resistances of the shaft and mine in the same proportion as in the previous example, but reckoning the power to remain the same throughout, the accompanying table shows the quantity that will pass with the various splits.

Having explained in the remarks on the previous table how the quantities have been found, it seems unnecessary to do so in this case; indeed, the tables are so constructed as to obviate as much as possible the necessity of explanation. The results given in this table may be found more directly by using the relative powers in the third column of the table; the quantities will be according to the cube root of these:

$$\text{With 2 splits} = \frac{\sqrt[3]{\frac{.001}{.03225}} \times 10000}{\sqrt[3]{\frac{.001}{.251}}} = 19817.$$

$$\text{With 3 splits} = \frac{\sqrt[3]{\frac{.001}{.010259}} \times 10000}{\sqrt[3]{\frac{.001}{.251}}} = 29030.$$

$$\text{With 4 splits} = \frac{\sqrt[3]{\frac{.001}{.00490625}} \times 10000}{\sqrt[3]{\frac{.001}{.251}}} = 37123.$$

Divisions of the current.	Relatively.			Actual.			
	s.	a.	$s\left(\frac{1}{a}\right)^3 = u$.	u.	s.	a.	$q = \sqrt[3]{\frac{u}{k\,s}} \times a$.
	1.	2.	3.	4.	5.	6.	7.
1 { Shafts......	1	10	.001	260.4	12,000	100	10,000
1 { Mine........	2	2	.25	65100.	24,000	20	10,000
			.251	65360.4			
2 { Shafts......	1	10	.001	2026.7	12,000	100	19,817⅜
2 { Mine........	2	4	.03125	63333.7	24,000	40	19,817⅜
			.03225	65360.4			
3 { Shafts......	1	10	.001	6370.4	12,000	100	29,030
3 { Mine........	2	6	.009259	58990.	24,000	60	29,030
			.010259	65360.4			
4 { Shafts......	1	10	.001	13322.5	12,000	100	37,123
4 { Mine........	2	8	.00390625	52037.9	24,000	80	37,123
			.00490625	65360.4			
5 { Shafts......	1	10	.001	21786.8	12,000	100	43,737
5 { Mine........	2	10	.002	43573.6	24,000	100	43,737
			.003	65360.4			
6 { Shafts......	1	10	.001	30295.9	12,000	100	48,818
6 { Mine........	2	12	.0011574	35064.5	24,000	120	48,818
			.0021574	65360.4			
10 { Shafts......	1	10	.001	52288.3	12,000	100	58,558
10 { Mine........	2	20	.00025	13072.1	24,000	200	58,558
			.00125	65360.4			

$$\text{With 5 splits}=\frac{\sqrt[3]{\dfrac{.001}{.003}}\times 10000}{\sqrt[3]{\dfrac{.001}{.251}}}=43737.$$

$$\text{With 6 splits}=\frac{\sqrt[3]{\dfrac{.001}{.0021574}}\times 10000}{\sqrt[3]{\dfrac{.001}{.251}}}=48818.$$

$$\text{With 10 splits}=\frac{\sqrt[3]{\dfrac{.001}{.00125}}\times 10000}{\sqrt[3]{\dfrac{.001}{.251}}}=58558.$$

41. Mr. Atkinson, in his *Treatise on Ventilation*, gives the quantities that will pass "supposing a mine to have such shafts and airways that when there are five equal splits of air the shaft resistances amount to one-half of the resistances offered by the mine . . . if before splitting the air at all we had a ventilation of 10,000 cubic feet of air per minute," with the same ventilating pressure in force (see page 59, fourth edition). As the figures are different from those obtained above, we have brought them into a tabular form, and worked out the pressure (p) from the formula $\frac{k s v^2}{a}$ as below.

It may be submitted that had Mr. Atkinson's quantities been correct, the pressure (p) should have been the same all the way down in the table; but it will be seen that the results are slightly different.

42. Again we have brought Mr. Atkinson's figures of page 60, fourth edition, into a tabular form and applied the rules $u=q\ p=vap$ to ascertain the power, and find the results are not quite the same in each case, though the difference is not very much, as will be seen from the last column of the table on this page.

Divisions of the current.		s.	a.	q, as per Mr. Atkinson.	$p=\frac{ksv^2}{a}$
1	Shafts.	12,000	100	10,000	.02604
	Mine..	24,000	20	10,000	6.51
					6.53604
2	Shafts.	12,000	100	27,892	.20258
	Mine..	24,000	40	27,892	6.33067
					6.53325
3	Shafts.	12,000	100	49,449	.63673
	Mine..	24,000	60	49,449	5.89566
					6.53239
4	Shafts.	12,000	100	71,527	1.33223
	Mine..	24,000	80	71,527	5.20407
					6.53630
5	Shafts.	12,000	100	90,789	2.14638
	Mine..	24,000	100	90,789	4.29277
					6.43915
6	Shafts.	12,000	100	107,800	3.02607
	Mine..	24,000	120	107,800	3.50236
					6.52843
10	Shafts.	12,000	100	141,710	5.22928
	Mine..	24,000	200	141,710	1.30732
					6.53660

Divisions of the air current.		s.	a.	q, as per Mr. Atkinson.	$p=\frac{ksv^2}{a}$	$u=qp=vap$
1	Shafts.	12,000	100	10,000	.026	260.4
	Mine..	24,000	20	10,000	6.51	65100.
						65360.4
2	Shafts.	12,000	100	19,813	.1022	2025.31
	Mine..	24,000	40	19,813	3.1940	63291.
						65316.31
3	Shafts.	12,000	100	29,022	.2193	6365.
	Mine..	24,000	60	29,022	2.0308	58938.
						65303.
4	Shafts.	12,000	100	37,121	.3588	13319.
	Mine..	24,000	80	37,121	1.4016	52028.
						65347.
5	Shafts.	12,000	100	43,736	.4981	21785.
	Mine..	24,000	100	43,736	.9962	43570.
						65355.
6	Shafts.	12,000	100	48,797	.6200	30254.
	Mine..	24,000	120	48,797	.7176	35017.
						65271.
10	Shafts.	12,000	100	58,556	.89286	52282.
	Mine..	24,000	200	58,556	.22321	13070.
						53526.

42[a]. A number of uneven splits subject to common pressure may be converted to one typical road that will offer the same resistance in passing the same quantity of air, in the following manner:

Let r = the sum of the separate results for each split of—

$$\frac{1}{\sqrt{\frac{\left(\frac{1}{a}\right)^2 \times s}{a}}}$$

Let a' = the area of the new typical road,
" s' = rubbing surface of ditto, then

$$\frac{\left(\frac{1}{r}\right)^2 \times a'}{\left(\frac{1}{a'}\right)^2} = s'$$

EXAMPLE:—Reduce the three uneven splits below to one road 6 ft. square that will offer the same resistance with the same quantity, or pass an equal quantity with the same pressure.

	a.	s.	$\frac{1}{\sqrt{\frac{\left(\frac{1}{a}\right)^2 \times s}{a}}}$
1	30	59400	.674201
2	36	57600	.900009
3	35	72000	.771678
			2.345888

$$\text{Then } \frac{\left(\frac{1}{2.34588}\right)^2 \times 36'}{\left(\frac{1}{36}\right)^2} = 8478\ s.$$

or $\frac{8478}{24} = 344\frac{1}{12}$; thus, a road 6 ft. square of this length or having a rubbing surface of 8478, will be equal to the three divided roads above.

Another example may be given to illustrate this rule. There are five unequal splits subject to one common pressure, with dimensions as below; find the value of s for a road 6 ft. square to give a resistance equal to that of all the splits together:

No.	Size.	Length.	$\frac{1}{\sqrt{\frac{\left(\frac{1}{a}\right)^2 \times s}{a}}}$
	ft. ft.		
1	8 × 8	1500	.6472313
2	5 × 5	1300	.7752171
3	4 × 5	1200	.6085806
4	6 × 6	1000	1.3942729
5	5 × 5	1300	.7752171
			4.2005190

$$\text{Then } \frac{\left(\frac{1}{4.200519}\right)^2 \times 36'}{\left(\frac{1}{36}\right)^2} = 2644.24\ s.,$$
the answer.

TO FIND THE QUANTITY THAT WILL RESULT FROM THE APPLICATION OF A GIVEN PRESSURE OR POWER IN A MINE HAVING UNEQUAL SPLITS, &c.

43. If there are a number of equal or unequal splits in a mine, all subject to one common pressure, the quantities that will pass in each split are in proportion to this formula:

$$\frac{1}{\sqrt{\frac{\left(\frac{1}{a}\right)^2 \times s}{a}}},$$

or finding p for an equal quantity passing in each split, the quantities in each split will be in proportion to $\frac{1}{\sqrt{p}}$.

44. The relative pressures or powers to pass the same quantity of air through aircourses of different areas and rubbing surfaces may be found by $\frac{s\left(\frac{1}{a}\right)^2}{a}$ or $s\left(\frac{1}{a}\right)^3$ which formulæ we have used in obtaining the figures contained in the third column of each of the tables on pages 284 and 285.

45. When the aircourses are of the same area and perimeter, and the pressure is the same, the quantities are in proportion to the reciprocal of the square root of the length $= \frac{1}{\sqrt{l}}$.

46. The water-gauge due to friction i 9 in. The downcast is 10 ft. in diameter and 70 fathoms deep, the upcast is 9

ft. diameter and 70 fathoms deep. The aircourses underground are as follows:

One 900 yards long 6 ft. × 5 ft.
" 800 " 6 ft. × 6 ft.
" 1,000 " 7 ft. × 5 ft.

Find the quantity of air passing, applying Mr. Atkinson's co-efficient of friction throughout—

.9 in. × 5.2 = 4.68 lbs. pressure.

In this case we proceed to find the pressure necessary for passing 40,000, which altogether amounts to 8.8561 lbs., then as $\sqrt{8.8561} : 40{,}000 :: \sqrt{4.68} =$ 29,077, as worked out in the table below, the formula at the head of each column explains where necessary the manner of proceeding; it has been assumed that the splits are subject to one common pressure.

Divisions of the air currents.	a.	s.	Relative pressures $= \dfrac{\left(\frac{1}{a}\right)^2 \times s}{a}$	Square root of relative pressures $= \sqrt{\dfrac{\left(\frac{1}{a}\right)^2 \times s}{a}}$ or $\sqrt{s\left(\frac{1}{a}\right)^3}$	Reciprocal of the sq. root of relative pressures = relative quantities $= \dfrac{1}{\sqrt{\dfrac{\left(\frac{1}{a}\right)^2 \times s}{a}}}$	Quantities in direct proportion to relative quantities.	p, for assumed quantity $= \dfrac{ksv^2}{a}$	p = in direct proport'n to figures in previous col.	$q = \sqrt{\dfrac{pa}{ks}}a$
Downcast.	78.54	13194 72				40,000	.9456	.4997	29,077
Upcast...	63.6174	11875.284				40,000	1.6014	.8462	29,077
1st airc'rse	30	59.400	2.1999956	1.4832382	.674201	11,496	} 6.3091	} .3341	8,357
2d airc'rse	36	57,600	1.2345332	1.1110999	.900009	15,346			11,156
3d airc'rse	35	72,000	1.679296	1.2958768	.771678	13 158			9,564
					2.345888	40,000	8.8561	4.68	29,077

47. The next table is given by way of exercise for the student—the question being, What quantity of air will pass through the mine with a total pressure of 8 lbs. per square foot, the current being divided as specified, Nos. 1 and 2 being the shafts, 3, 4, 5, and 6 splits, subject to the same pressure? It is not necessary here to explain how the figures in the first seven columns of this table have been obtained, but those of column 8 are on the assumption that 40,000 ft. of air pass through each division (any other quantity might have been assumed); column 9 is the the reciprocal of the square root of the pressure given in column 8. In column 10, we give the quantities that pass in each division when the total is 40,000; of course the two shafts (1 and 2) pass the total quantity of 40,000, and the quantity in each division underground is in direct pro-

No.	Size.	Length.	Perimeter.	s.	a.	q.	$p = \dfrac{ksv^2}{a}$	$\dfrac{1}{\sqrt{p}}$	q.	p.	p in proportion to col. 11, total being 8 lbs.	Actual quantity for the total pressure of 8 lbs.	u.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1	8×8	900	32	28,800	64	40,000			40,000	8.814	2.147	30,012	64,436
2	7×7	900	28	25,200	49	40,000			40,000	7.437	4.187	30,012	125,660
3	8×3	1,500	22	33,000	24	40,000	82.88188	.1098424	7,558	} 2.959	} 1.666	5,671	9,448
4	5×5	1,300	20	26,000	25	40,000	57.77408	.1315629	9,053			6,792	11,315
5	4×5	1,200	18	21,600	20	40,000	93.74400	.1032828	7,107			5,332	8,883
6	6×6	1,000	24	24,000	36	40,000	17.86005	.2366237	16,282			12,217	20,354
								.5813118	40,000	14.210	8.000	30,012	240,096

portion to the figures given in column 9. In column 11 it is seen that the total pressure required to pass 40,000 is 14.21 lbs., but as only 8 lbs. is the pressure in force, we proportion the figures in column 12 with those of 11, so that they amount to 8 lbs. and then we find if $\sqrt{14.21}$ give 40,000 that $\sqrt{8}$ will give 30,012, and that the quantities passing in each split 3, 4, 5, and 6 will be according to the figures given in column 13, and the total power (u) as per column 14, will be 240,096.

48. By way of exercise for the student it has been further assumed that another

No.	Size.	Length.	Perimeter.	$s.$	$a.$	$\frac{1}{\sqrt{\frac{\left(\frac{1}{a}\right)^2 \times s.}{a}}}$	$q.$	$p.$	$q.$	$p.$	$u.$
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1	8×8	900	32	28,800	64		30,012	2.147	30,744	2.2583	69,275
2	7×7	900	28	25,200	49		30,012	4.187	30,744	4.3933	135,068
3	8×3	1,500	22	33,000	24	.6473508	4,624		4,737		5,509
4	5×5	1,300	20	26,000	25	.7054475	5,539		5,674		6,599
5	4×5	1,200	18	21,600	20	.6085806	4,348	1.108	4,454	1.1630	5,180
6	6×6	1,000	24	24.000	36	1.3942729	9,962		10,205		11,868
7	5×5	1,300	20	26,000	25	.7054475	5,539		5,674		6,599
						4.0610993	30,012	7.442	30,744	7.8096	240,098

aircourse (No. 7) 5×5 and 1,300 ft. long be added to those enumerated in the previous paragraph, and that the power in force remains the same. With these conditions the quantity passing, it will be seen, is only increased from 30,012 to 30,744, as per table on this page.

In this case we have proportioned the quantities in each split by the figures in column 7; and in taking 30,012 as the total quantity of air passing we find the pressure, as per column 9, to be 7,442; this multiplied by the quantity gives 223,349 units; then we find if $\sqrt[3]{223349}$ give 30,012 that the $\sqrt[3]{240096}$ gives 30,744, and the quantity in each split is proportioned again according to the figures in column 7. The pressure, p, in column 11 may be obtained by proportioning it with the figures in columns 8, 9, and 10, or by working out directly from the quantity in column 10 by the formula—$p=\frac{k s v^2}{a}$, and u in column 12 is obtained by multiplying the figures in columns 10 and 11 together; and it will be seen that the total units in this column amount to 240,098, which is correct within 2 units in the previous table.

49. Suppose a mine to have two splits of air only, one offering five times as much resistance as the other, and that the ventilating pressure required to circulate the air through the shafts and undivided airways is one-twelfth of the whole ventilating pressure. With a total quantity of 100,000 feet passing per minute, and putting the rubbing surface of the shafts at 10,000 and area at 100, then the figures in the table below will show the relative rubbing surfaces, areas, buantities, and pressures meeting these conditions.

Divisions of the air.	$s.$	$a.$	$q.$	$p.$
Shafts........	10,000	100	100,000	2.17
Mine........	1,151,912	100	30,902	23.87
	230,388	100	69,098	
				26.04

50. If the pressure remain the same as stated in previous paragraph, and there are three splits offering resistances in the ratio of 3, 2, 1, then the relative quantities, rubbing surfaces, areas, and pressures will be according to the following table:

Divisions of the air.	s.	a.	q.	p.
Shafts........	10,000	100	148,869	4.81
Mine.......	691,150	100	37,623	
	460,767	100	46,079	21.23
	230,383	100	65,167	
				26.04

The examples given in this and the previous paragraph are to be found in another form at page 182 in the Transactions of the North of England Institute of Mining Engineers, Vol. VI.

51. If the downcast and upcast shafts of a colliery are each 180 fathoms deep and 12 ft. 5 in. diameter, and with one undivided aircourse in the mine having $a=36$ and $s=120,000$, the quantity of air circulating is 15,000 cubic feet per minute, what quantity will pass when there are 2, 3, 4, 5, and 6 equal splits, the pressure remaining the same? In the first place we find the total pressure required to pass 15,000 ft. of air with only one aircourse is 12.78954 lbs., then we find what the relative pressures are on 15,000 in the case of all the splits, as per column 4; the pressure in column 5 is then apportioned directly according to the figures in column 4; and from the pressure in column 5 we get the quantity in column 6 by the rule—$\sqrt{\frac{p\,a}{k\,s}} \times a$ and u is got by multiplying p and q together.

Supposing it be required to know what quantity will pass with the power (u) remaining the same, we find by the table that this amounts to 191,843 units when the air is passing round the mine in one current, then by the table we see that with the same pressure there are 39,968 feet of air passing with two splits, and that the power (u) amounts to 511,172, then we say

As $\sqrt[3]{511172} : 39968 :: \sqrt[3]{191843} : 28666$, the quantity of air that will pass when

Divisions of the current.		a.	s.	Relative pressures on a quantity of 15,000= $\frac{k s v^2}{a}$	p.	q.	u.
No.	1.	2.	3.	4.	5.	6.	7.
1	Shafts....	121.087	84,240		.231669	15,000	3,475
	Mine......	36	120,000		12.557871	15,000	188,368
					12.789540		191,843
2	Shafts....	121.087	84,240	.231669	1.644796	39,968	
	Mine......	72	120,000	1.569734	11.144744	39,968	
				1.801403	12.789540		511,172
3	Shafts....	121.087	84,240	.231669	4.252368	64,265	
	Mine......	108	120,000	.465106	8.537177	64,265	
				.696775	12.789540		821,920
4	Shafts....	121.087	84,240	.231669	6.924602	82,008	
	Mine......	.144	120,000	.196217	5.864938	82,008	
				.427886	12.789540		1,048,845
5	Shafts....	121.087	84,240	.231669	8.920971	93,082	
	Mine......	180	120,000	.100463	3 868569	93,082	
				.332132	12.789540		1,190,476
6	Shafts....	121.087	84,240	.231669	10.223839	99,647	.
	Mine......	216	120,000	.058138	2.565701	99,647	
				.289807	12.789540		1,274,439

there are two equal splits, and the power remains the same, or we work out the results in the case of all the splits as follows:

$$\text{With 2 splits} = \frac{\sqrt[3]{191843} \times 39968}{\sqrt[3]{511172}} = 28666$$

$$\text{With 3 splits} = \frac{\sqrt[3]{191843} \times 64265}{\sqrt[3]{821920}} = 39347$$

$$\text{With 4 splits} = \frac{\sqrt[3]{191843} \times 82008}{\sqrt[3]{1048845}} = 46291$$

$$\text{With 5 splits} = \frac{\sqrt[3]{191843} \times 93082}{\sqrt[3]{1190476}} = 50370$$

$$\text{With 6 splits} = \frac{\sqrt[3]{191843} \times 99647}{\sqrt[3]{1274439}} = 52617$$

ASCENSIONAL VENTILATION.

52. By ascensional ventilation is meant the art of conducting the air underground so that it shall in the first place go directly to the lowest part of the workings and afterwards rise as it returns to the bottom of the upcast shaft. The intake generally being colder than the return, by this system return air is made to ascend and not descend. There is a loss of power in conducting return air downwards to the upcast, and this is a practice that should be avoided as much as possible.

53. The rules and tables referring to the friction of air and to the different quantities that will circulate with certain pressures, as given in the previous chapters, apply only to horizontal channels and not to dip and rise roads; for in practice it is found, whilst the quantities of air that will pass in different splits in the same horizontal plane preserve the same proportion whatever the ventilating pressure may be, such is not the case with dip and rise plits.

54. The reason of this is that there is a difference between the density of the intake and return air due to change of temperature, the mixture of watery vapor, the emission of gases, &c., and as the return air of any current is generally less dense than the intake (on account of the gases emitted being usually lighter than common air, &c.) there is mostly a natural influence at work in favor of the intake current passing to the dip, and returning by an ascending route, and against the air going first to the rise and returning by a descending road. Supposing a dip and rise split to be subject to one common ventilating pressure, in the case of the dip split there is to be added the pressure due to natural influences, in the case of the rise split the pressure due to natural influences is to be deducted from the general ventilating pressure, and thus it happens if there be a long split and a short one, both level, in order to pass equal quantities of air in each it will be necessary to put a regulator in the short one; and on reducing or increasing the ventilating pressure the quantities will still be equal, but if the long one is a dip split and the short one a level one, on reducing the total quantity of air the long split will get a greater proportion than originally. On the other hand, if the long split is a rise one and the short split a horizontal one, on reducing the total quantity of air the long split passes less and the short one more than the original share. This fact, so repeatedly proved in practice, clearly shows the value of the principle of ascensional ventilation and the mistake in carrying return air down the bank. If, however, the returns were charged with gases heavier than common air to such an extent as to render them more dense than the intake air, the opposite results would take place on reducing or increasing the general ventilating pressure in the case of dip and rise splits. This, however, is an exceptional case, for, as said before, the return air of mines is generally less dense in consequence of being usually higher in temperature, and impregnated with the lighter gases; and it is therefore, speaking generally, wrong in principle to bring return air down the hill. The descent of return air in places which give off fire damp has been, and is likely to be, the cause of serious explosions.

55. In collieries giving off fire damp it is well to have the return aircourse on the upper side of the workings; by this means the gas will be naturally drained away by gravity from the goaves or where workmen are employed.

56. If the ascensional principle of ventilation be carried out, the exudation of carburetted hydrogen in a mine will have the effect of increasing the ventilation. The light specific gravity of the fire

damp, as compared with that of air, will be equal to an additional ventilating pressure. This principle appears to be well understood in Belgium and in Westphalia, particularly so in the last-mentioned coalfield, where, according to the experience of the writer, it is the prevailing system.

57. In furnace ventilation the best current of air is produced by having the furnace placed on the dip side of the underground workings, because in that case a longer motive column or ventilating pressure is obtained; but in steep-lying seams the advantage derived by the natural ascendancy of warm air and light gas is not only lost, but an additional pressure equivalent to this advantage is required to bring the light air down to the bottom of the upcast. Hence, ventilating fans made to exhaust the air from a shaft on the rise side of the workings are both in point of economy and safety better for ventilating steep seams than furnaces placed on the dip side.

58. If we suppose the rise workings to reach the vertical height of 50 fathoms, and the temperature of the intake be 55 degs. and return 85 degs., there will be a natural pressure due to temperature alone of 1 lb. per square foot, or one-fifth of an inch of water gauge in favor of mechanical ventilation with upcast shaft at the rise of the workings, and against furnace ventilation with the upcast at the dip, in addition to the extra resistance consequent on the increased length of aircourse and upcast. In order to make this plain to the student, we take from the table of the weight of air given under paragraph 6 the weight of a foot at 55 degs. =.0773515, and multiply this by 300=23.20545, and deduct the weight at 85 degs. =.0730858 multiplied by 300=21.192574, which gives a difference of 1.01 lb.

59. The average temperature of a furnace upcast may generally be taken at 100 degs. (at least) more than that of the mine, and consequently the increased pressure obtained at the bottom of the upcast by this increased length of heated air column will overcome any local pressure in the mine and compel the air to travel down-hill from the rise workings to the furnace, but this will be at the expense of additional fuel.

60. It has been stated that the gases emitted from mines are generally such as to render the return air lighter than the intake. This, however, depends on the specific gravity of the gas. The table following shows the specific gravity of the various gases met with in mines and the relative altitude they usually assume:

	S.G.
Hydrogen	0.069
Carburetted hydrogen	0.550
Aqueous vapor	0.620
Nitrogen and Miasma	0.976
Olefiant	0.980
Air	1.000
Oxygen	1.100
Sulphuretted hydrogen	1.190
Carbonic acid	1.520
Sulphurous acid	2.120

Those gases which are lighter than air have an influence in favor of the ascensional principle of ventilation; those which are heavier will act prejudicially to it.

VELOCITY OF AIR.

A velocity of 6 in. per second or 30 ft. per minute is enough to deflect the flame of a candle, and 3 ft. per second is sufficient to remove and render harmless the ordinary discharges of fire damp. A return aircourse 7 ft. square passing 30,000 cubic feet of air per minute gives a velocity of about 10 ft. per second. In many of the furnace pits of the North of England the air travels at a velocity as high as 30 ft. per second. It is not always practicable, however desirable, to reduce the velocity in returns or upcast shafts to a minimum, but it is very important that the air in the working parts of a mine should not travel at less than say 2 ft. per second, or more than 7 ft. The medium between these would be the best average velocity; but a very much greater velocity than this is attained in some collieries.

62. There are several reasons why air should not travel at a high velocity. One is because, if it be very much surcharged with fire damp, enough to render it inflammable, there is a danger of some of the commonly used lamps exploding. Another reason is that the pressure required to overcome the friction is according to the square of the velocity, and the power according to its cube. The following table shows the relative press-

ures and powers required to move the air through the same aircourse at the velocities stated:

Velocity in ft. per second.	Relative pressures.	Relative powers.
3	1.	1.
4	1.77	2.37
5	2.77	4.63
6	4.	8.
7	5.44	12.70
8	7.11	18.96
9	9.	27.
10	11.11	37.03
12	16.	64.
14	21.77	101.63
16	28.44	151.70

Thus we see there is 16 times the pressure and 64 times the power required to pass the air through the same channel, at a velocity of 12 ft. per second that is necessary at 3 ft. per second. Thirdly, when air travels too rapidly it is disagreeable to the workmen and all who have to move in it; and it is difficult to prevent the light from being blown out.

63. Each split should have a current of 8,000 or 10,000 cubic feet per minute and the latter quantity at a velocity of 5 ft. per second would require an area of 33 square feet.

An inflammable mixture of pit gas and air, moving at the rate of 8 ft. per second will explode most of the ordinary safety (?) lamps.

THE CO-EFFICIENT OF FRICTION.

64. Throughout this treatise we have used the co-efficient of Mr. Atkinson, namely, .0000000217 lb. for each foot of rubbing surface, and a velocity of 1 ft. per minute. From this we find that $v=6788$

$$\sqrt{\frac{pa}{s}}, \text{ because } \sqrt{\frac{1}{.0000000217}}=6788.$$

65. Mr. D. K. Clark, in his most excellent book, *Rules, Tables and Data for Mechanical Engineers*, gives the following formula for the "flow of air through passages of any form of section" (substituting the notation used throughout these papers it is):

$$v=796\sqrt{\frac{wa}{s}}$$

and to bring this into the same terms as above:

$$\frac{796\times60}{\sqrt{5.2}}=20,944,$$

therefore:

$$v=20,944\sqrt{\frac{pa}{s}}$$

66. M. Devillez, in his *Ventilation des Mines*, uses a co-efficient which is equal to .00000000951 lb. for each foot of rubbing surface and a velocity of 1 ft. per minute, now as:

$$\sqrt{\frac{1}{.00000000951}}=10,253\ v=10,253\sqrt{\frac{pa}{s}}$$

67. Recapitulating, we see that the velocity is found according to these three authorities as below:

Per Atkinson, $v=\ 6,788\sqrt{\frac{pa}{s}}$

Per Devillez, $v=10,253\sqrt{\frac{pa}{s}}$

Per Clark, $v=20,944\sqrt{\frac{pa}{s}}$

68. The writer is inclined to think that Mr Clark's formula is deduced from experiments with passages having smoother sides than those of underground roads generally, and consequently the friction is not so great; he has confidence in the result obtained by M. Devillez, but thinks until further experiments have been made it would be sufficiently near, as an average for underground passages, to use $10,000\sqrt{\frac{pa}{s}}$. This would be equal to .00000001 pound per square foot of rubbing surface, or $\frac{1}{100,000,000}$ for a velocity of one foot per minute, or .01 lb. or $\frac{1}{100}$ for a velocity of 1,000 ft. per minute, and these are factors that could be both easily remembered and used in calculation.

NOTE.

69. In the preceding pages calculations have been gone into to show the quantities of air that will circulate under certain conditions; it is necessary to state that these conditions never exist practically; for example, "equal splitting," as has

been explained under paragraph 31, cannot very well exist in a practical sense; then again in considering "unequal splitting," it has been assumed that the splits are all subject to one pressure; this can only be the case when all the splits divide from the main current at one point, and reunite again in the return at one point, which will not be found to be the case practically. It has already been pointed out in the earlier pages that one of the conditions—assumed to exist—is wanting in the case of dip and rise splits. Another condition affecting the consideration of the quantities that will pass with various powers or pressures is the co-efficient of friction; in the calculations it has been assumed that one co-efficient applies throughout the whole ramifications of the mine, from the entrance of the air at the mouth of the downcast till it escapes at the top of the upcast; but from experiment it has been found that the co-efficient varies with the nature of the rubbing surface; that in an arched tunnel or brick-lined shaft, for example, it is not nearly so much as for the ordinary channels of a mine. It has likewise been assumed that all the air which enters the mine passes completely through it, but this is not the case practically; air escapes at doors, stoppings, crossings, brattice, and through goaves, &c., and this to a very large extent in some collieries.

70. The amount of this fugitive air, if it may be so called, is not always a criterion of the ability displayed in carrying out the ventilation; in collieries having good means of producing air, and with limited workings, it is more permissible than in extensive collieries which require all the air in-bye that can be obtained; in such cases as the latter care must be taken to prevent the escape of air by taking the short route to the return, instead of passing through the working places.

71. All open places in a coal mine, whether in work or not, should have air passed through them, and in no case should old workings be shut up with air-tight stoppings; such a practice is very likely to lead to some casualty through places of this kind becoming dangerous magazines of gas.

72. It is hoped the calculations that have been gone into may be of some assistance to students in undertanding the question. The principal matter of this essay was worked out some twelve months ago, when the writer intended to consider the subject further; since then, however, his engagements have prevented him from devoting the necessary time to it, and for this reason certain experiments on the subject cannot at present be utilized.

ON THE ECONOMICAL USE OF GAS ENGINES FOR THE PRODUCTION OF ELECTRICITY.*

From "Nature."

The lecturer pointed out, that as long as the chief practical use of electricity was in telegraphy it was the quickness of action, rather than the ability to transmit large amounts of power to a distance, that formed the chief feature in the employment of electricity; but that in this exhibition the numerous practical examples of the electric transmission of power, rather than the electric transmission of signals, formed without doubt the leading feature.

Much had been heard about the dynamo-electric machines which generate the electric current; but while electricians were engaged in considering the differences between the various kinds of these machines and the improvements that can be effected in them, the mechanical engineer should give his careful attention to the possible improvements that can be made in the engines that drive the electric generators.

As long as the lighting of our large cities was performed by gas the cheap manufacture of illuminating gas was the important question, but now that electric lighting bids fair to displace other systems the question that has special interest is, not the extraction of illuminating gas from coal, but the employ-

* Abstract of a lecture delivered in French in the Salle du Congres, at the Electrical Exhibition, Paris, by Prof. W. E. Ayrton, F.R.S.

ment of the store of energy in the latter to set in rapid rotation dynamo-electric machines for producing the electric current used in lighting.

At present steam engines are chiefly used to drive the dynamo-machines, but even with the best engines and boilers it is well known that the fuel consumption is excessive compared with the actual work done. So good an authority as Sir William Armstrong has recently said that with a good condensing engine only one-tenth of the whole heat energy of the fuel is realized in useful work, and this is no exaggeration of facts. What therefore must be said of a small engine and boiler of the ordinary type? The main reason why the efficiency of even the best steam engines is so low is because in an ordinary engine steam can only be used at a comparatively low temperature; for it can be proved that, with the temperatures which can be used in condensing engines, the efficiency of even an imaginary perfect engine, without friction and loss of heat, cannot exceed $\frac{2}{10}$, or only double the efficiency of a good modern steam engine; that is to say that a good engine of large size uses only $\frac{1}{10}$ of the total heat, and that it is not possible to use more than $\frac{2}{10}$ with an engine of perfect mechanism.

It may be assumed that in large compound marine engines the fuel consumption is about 2 lbs. per indicated horse power, but it cannot yet be said that engines of this class and of very high power will be used in central stations for electrical purposes: at any rate it must be remembered that besides other considerations there is a great objection to the use of a single very large engine to electrically light a district, for the accidental stoppage of this engine would plunge the whole neighborhood into darkness.

Engines and boilers of the portable type are those generally used now for electrical purposes, and in a competition in England of several of the best engines of this class the fuel consumption was about 4 lbs. per indicated horse power per hour; but in daily practical work it may be assumed that 6 to 7 lbs. more nearly represent their usual fuel consumption. This gives an efficiency of only about $\frac{1}{30}$.

With a hot-air engine there is this great disadvantage, that it is extremely difficult to prevent the lubricants from being burnt and the air vessel being injured by heat, since the latter vessel must be kept as hot or hotter than the air, because the temperature of the air is raised by an *external* fire. The only other motor suitable for electrical purposes (apart from machines driven by water or wind power) is the gas engine. In the latter, the power is obtained by the admission of an explosive mixture of gas and air into the cylinder, and the piston is driven by the explosion produced on the ignition of this mixture.

Now, there is this great difference between a hot-air engine and a gas engine, that in the latter the high temperature arising from the explosion is produced *inside* the cylinder, and not outside; so that, although the gas at the moment after explosion is extremely hot, the cylinder, piston, and lubricant may be kept cool by an external stream of water, which is of course impossible in a hot-air engine where the air is heated from the outside. Again, the very high temperature developed in the cylinder after the explosion has taken place, is rapidly reduced by the piston doing work before there is time for the gas to give up much of its heat to the cylinder and piston. Steam, however, can only be used at a very high temperature, provided the apparatus is made exceedingly strong.

With the present temperatures employed, the theoretical efficiency of a gas engine might be raised from 56 to 75 per cent., if loss of heat by conduction, radiation, and convection, as well as friction, could be prevented; while in a condensing steam engine the greatest efficiency that could be obtained with the present temperatures employed could never exceed about 20 per cent.

It was thus shown that practically a gas engine admits of being worked with much greater *efficiency* than either a steam engine or a hot-air engine—that is to say, the percentage of heat the former turns into mechanical work is much greater than with the latter two. It was, however, necessary to consider the *economy* of working, which depends on the relative price of the fuel employed, and other items of working cost. Comparative estimates were therefore given of the working cost of a steam engine of a portable type and of an Otto gas engine, both indicating 30 horse power, for 300 days of nine hours each (the horse power about necessary to keep alive the 400 Swan incandescent lamps used to illuminate the Salle du Congres during this lecture). The cost of the coal gas was taken at three shillings per 1,000 cubic feet (or about 13½ centimes per cubic meter, only about half the actual price in Paris), and it was thus seen that, in spite of the very great relative efficiency of the gas engine, the cost of working with ordinary coal gas is greater than in the case of the steam engine. Ordinary coal gas, however, has been prepared for producing not heat, but light, and has therefore been elaborately purified at a considerable cost, so that when used in a gas engine it is used for a purpose quite different from that for which it was intended.

A gas engine burning illuminating gas is, in fact, in the same position as was a few years ago an electromotor, or machine for converting electric energy into mechanical power. An electromotor is an extremely efficient machine, but the fuel burnt to produce the electricity was, until quite recently, zinc, and consequently was far too expensive to allow the use of electromotors to be commercially successful. So, in the same way, if it is attempted to work gas engines by burning illuminating gas at even 13½ centimes the cubic meter, or half the actual price of the ordinary gas in Paris, they cannot even be worked as economically as steam engines, in spite of their superior efficiency and of the much smaller cost for superintendence. But if it be possible to manufacture for their use a cheap heating gas in the same way as it is now possible to produce electric energy economically by burning coal, which is a much cheaper fuel than zinc, then the result, as you will see, becomes just the reverse, and small gas engines driven with such gas not only greatly surpass in economy steam engines of the same size, but produce energy at a cheaper rate per horse power than the largest steam engines ever made.

The lecturer then described what had been done by Dr. Siemens and others who have made a heating gas for furnace work by means of passing air only, or air with a small admixture of steam, through a mass of burning fuel. Such gas, however, contains too much nitrogen (60 to 70 per cent.) to be suitable for gas engines and other purposes requiring it to be used in small quantities, and the plant is large and costly. Reference was then made to what had been done by Mr. Dowson of London, who had perfected a gas-generating apparatus, into which he passes steam at pressure with a certain portion of air. This he effects by an arrangement similar to a steam-engine injector or a jet pump. The air thus drawn into the generator serves to keep the column of fuel through which it passes at a high temperature, without an exterior fire, so that the decomposition of the steam and the other chemical reactions take place without interruption. The working of the generator is thus regular, and the gas is produced without fluctuations in quality.

Experiments were made with a eudiometer, in which were three volumes of the Dowson gas and one of oxygen, and on exploding the mixture, 36 per cent. of the total disappeared. This corresponded with the following composition of the Dowson gas, viz. hydrogen, 20 per cent.; carbon monoxide, 30 per cent.; carbon dioxide, 3 per cent.; and nitrogen, 47 per cent. by volume. It was also shown that this gas burns without smoke or any deposit of soot on a piece of porcelain, whether placed above or in the middle of the flame.

About 50 per cent. of this gas is combustible, and its calorific power, or the number of heat units produced by the combustion of a cubic meter, is 1,558,358. Its calorific intensity is 2,268° C. To compare it with ordinary coal gas we may take the calorific power of a cubic meter of the latter to be 5,590,399, and its calorific intensity as 2,554° C.

In the Otto gas engines a large proportion of air is mixed with the coal gas, so that the effect of the explosion may continue during the stroke of the piston by the air taking up some of the heat produced; and as the Dowson gas requires less air for its combustion, it is found that in the same cylinder there is not more nitrogen and unused oxygen in the charge of Dowson gas with its mixture of air, than with coal gas and the quantity of air which is given to the latter. That is to say, that the same power can be developed in the engine with coal gas or Dowson gas if the supply of gas and air be exactly proportioned.

The comparative explosive force of the two gases calculated in the usual way is as 3.4 : 1, *i.e.* coal gas has 3.4 times more energy than the Dowson gas. But because the combustion of carbon monoxide proceeds more slowly than that of carburetted hydrogen gases, and because the diluents present in the cylinder affect the weaker gases more than the coal gas, in practice, with an Otto engine five volumes of the Dowson gas are used for one volume of coal gas.

A table was given showing all the working expenses of an Otto gas engine, indicating 30 horse power, and driven by the Dowson gas for 300 days of nine hours each, so that these expenses might be compared with those given for the steam engine and the gas engine worked with coal gas. These figues showed that a gas engine, worked with Dowson gas, cost about 45½ per cent. less than when worked with coal gas at 3s. per 1,000 cubic feet, and about 47½ per cent. less than a steam engine of the portable type, after allowing in each case for repairs and depreciations, and interest on capital outlay. The most striking feature, however, was that with a steam engine consuming 6 lbs. of coal per indicated horse power per hour, and without adding any allowance for fuel used in getting up steam, and after work is done 217 tons of coal are required to give the same power as 39 tons of coal converted into gas by the Dowson process. This represents a saving of about 88 per cent. in the weight of fuel.

Another practical consideration was that the quantity of the Dowson gas required to give the equivalent of 1,000 cubic feet of coal gas was only 24 to 27 per cent. of the weight of the coal necessary for the latter. A further point of great interest is that a series of trials made with 3½ horse power (nominal) Otto engines driven by the Dowson gas, have proved that 1 *horsepower* (*indicated*) *is obtained with a consumption of gas derived from* 1.46 *lbs. of coal*, after allowing for the gas burnt in the manufacture of the gas, as well as ten per cent for impurities and waste of the coal. With gas engines of larger power the loss due to friction is proportionally less, and the consumption of gas per indicated horse power is less, thus with a 16 horse power (nominal) engine which can indicate up to about 40 horse power, the Dowson gas required would be about 90 cubic feet per indicated horse power per hour, and this would give a consumption of coal of *only* 1.2 *indicated horse power per hour.*

Moreover, with a cheap heating gas not only can a saving in the motive power be effected for electric lighting, but this gas can also be used for domestic and industrial purposes, such as cooking and heating. It burns without smoke, so that when it is used in districts where there are many factories, or where much coal is consumed, not only will a great saving be effected, but in addition there will be freedom from a dark depressing atmosphere—the presence of which, the lecturer remarked, was the bane of London, and the absence of which formed the greatest charm of Paris.

The New Faure Accumulator.—After trying lead plates covered with minium and sheathed in flannel, then rolled into a spiral form for the Faure accumulator, recourse was had to square plates standing side by side. M. Emile Reynier, however, electrician to the Force et Lumiere Company, has modified the battery by returning to the original shape of a spiral roll for the plates, and sheathing them in a sort of linen serge instead of flannel, after they have received their coat of minium. He also encloses the plates in a glass vessel instead of a wooden trough, principally because the electrician can more easily see if there is any discharge of gas bubbles from the plates. In charging, the appearance of these bubbles, if the cell is a good one, indicates that the supply of current ought to be suspended, because the cell is full. Should the bubbles appear before the charging is complete the cell is considered faulty. The reason of this is that the oxygen liberated on the electro-positive plate ought to be entirely used in oxidizing the minium, and it is only when that oxidation is complete that the gas should rise from the plate.

THE COMBINATION SYSTEM OF STEAM HEATING FOR TOWNS AND VILLAGES.

By CAPT. DOUGLAS GALTON, C.B., Hon. D.C.L., F.R.S., &c., &c.

From the "Journal of the Society of Arts."

The vast increase in the size of the metropolis, and of other towns in the United Kingdom, has brought into prominence the question of how to maintain a pure atmosphere over such extensive congregations of houses. One of the most prominent causes of impurity in a town air is smoke and soot.

Where vapor of water or fog prevails, it has been shown that when particles of coal tar are floating in the atmoshere, they attach themselves to the watery vesicles of fog or cloud, and coat them with an oily film, which retards the evaporation of the water. These conditions operate to give a greater degree of permanence to a cloud thus composed of watery vesicles and smoke, than clouds consisting of water vapor alone posseses.

The exhibition which has been opened at South Kensington exemplifies very clearly that this cause of impurity is, to a large extent, under our own control, and that, with more careful and scientific appliances, we might easily reduce the quantity of visible impurity which our chimnies vomit into the atmosphere.

The various apparatus which are exhibited may be divided into those, on the one hand, which deal with the method of consuming coal in a smokeless manner, in each separate house; and, on the other hand, those which make use of gas, and thus require some central establishment to create their smokeless fuel, and transmit it to the several houses, to be there applied to heating and cooking purposes.

The Exhibition does not, however, contain any description of a method of heating which was proposed a few years ago, and has actually been adopted in the United States of America. This provides for consuming the fuel at a central source of supply, and sending thence the heat itself to supply the several houses in connection with it, and the system thus dispenses with the necessity for consuming the fuel in each individual house. This system is called the Combination System of Steam-heating for Cities and Villages, and was devised by Mr. Holley.

The system of heating houses by steam, instead of by hot water, has obtained a large development in the United States.

In the ordinary steam-heating apparatus which is in general use in houses in the United States, and in which the steam is under pressure, the flow pipe should be carried in as direct a line as possible from the boiler to the highest point; all the coils for heating should be placed on the return pipe, which should be laid in a uniformly descending line back to the boiler, so arranged as to prevent the lodgment of any condensed water on its way there, it being a source of economy in steam heating that the condensed water should flow back to the boiler.

The use of steam for heating pipes for warming purposes possesses certain advantages, and when the object is to warm air, the higher the temperature of the pipes the greater is the comparative effect. When compared with pipes heated by hot water under ordinary conditions, steam-heated pipes also possess the advantage that when a high temperature is obtained in the pipes heated by steam, there results the consequent radiation of a large proportion of heat to the walls of a room.

Steam heating possesses some disadvantages. The steam frequently makes unpleasant noises, if air or water lodges in the pipes. The heat given out is very great, and becomes often oppressive. Under the ordinary arrangements for steam heating, the temperature of the pipes cannot be regulated as with hot water. This latter objection is met to some extent by separting the coils into parts, which can be put in operation consecutively.

Mr. Holley, in the system of combined steam heating, which is about to be described, has advised an arrangement of pipes, which he terms the atmospheric radiator, to enable the temperature of the pipes to be regulated. In the combination system of steam heating, the steam, when once it enters the house, becomes the property of the occupier of the house, and the condensed water does not return to the boiler: the steam for the radiators is taken out of the flow-pipe through a valve, regulated by a thermostat, so arranged as to open and close the valves, admitting steam to the radiators; this thermostat may be adjusted to operate within ten degrees of temperature, so that the heat of a room may be automatically maintained at about the temperature desired. The steam is admitted at the top of the radiator, through the valves, in such quantity as is desired, the bottom being open; the amount of steam admitted is determined by the temperature which it is desired to maintain, and by the amount of radiating surface. Thus, if a moderate temperature is required, a little steam will be admitted to the upper portion of the tubes. The heat from this small quantity of steam will be rapidly diffused by the surface of the radiator through the air of the room, and the inlet valve can be so adjusted as to control the amount of steam admitted; by this means the temperature of the room may be maintained at any required degree. The advantages claimed for these radiators are economy of manufacture, and ease of graduating to all weather; they may be made of tin, or galvanized iron, of any required height and design. The steam and water of condensation give off all their heat, and there being no valve in the return pipe, and no pressure, there is no cracking and spluttering noise, as in pressure radiators.

The steam, after it has passed into these radiators, cools down and becomes water, and passes entirely away from the steam pipes, to be applied to such other purposes as the house owner desires, as will presently be explained.

Thus, in the ordinary system of heating by steam, in use in houses in the United States, the steam circulates continually from the boiler to the radiator, and returns as condensed water to the boiler; whereas, in the Combination system, the steam does not circulate back to the boiler, but, after it has passed into the house, passes away as water. That is to say, the steam in this system is taken from a steam main, laid through the streets, just as gas or water is taken from a main, and the heat from the steam is consumed in the houses in such a manner as owner of the house thinks fit.

The following is the general arrangement of the system:—The boilers are placed in a convenient central situation. The results given by Mr. Holley of a series of experiments on several boilers in use by him, show that, at Lockport, he evaporated, on an average, from 6 lbs. to 9.5 lbs. of water per pound of coal; this, of course, is a matter greatly depending on the quality of the fuel. Mr. Holley speaks in high terms of the Murphy smokeless furnaces, with regard to which he says:—"The perfect combustion and consequent total abolition of smoke from bituminous coal, and relative economy in the production of steam, are not the only points of superiority, as its cleanliness, ease of management and saving of labor, are almost equally important. The stocking of the boiler resolves itself merely into dumping the coal from cars into the bin above the fire box in front of the boiler, and occasionally pulling it towards the feed. A little engine carries it into the coking chamber, dumps it at the proper time on the grate bars, and, by means of levers moving the shake bars to and fro, slowly clears the bars of ashes. The doors are never opened, and one attendant, without a fireman's skill, will manage a battery of six boilers worked by the same power." This arrangement of furnace appears to have some resemblance to the McDougall furnace in the Smoke Abatement Exhibition.

From the boiler the steam passes into the main pipes and lateral or branch pipes. These have been made of lap-welded wrought-iron steam pipes. They vary in size according to the duty they have to perform. The largest yet laid is stated to be 12 inches diameter. The maximum steam pressure would be 100 pounds per square inch; but the pipes are made to resist strains many times in excess of the maximum pressure to which they can be subjected, and they are carefully tested.

It is essential to guard against the condensation, for, unless steam can be transmitted to considerable distances without too great loss by condensation, all devices to use it in buildings, however ingenious, would, of course, be useless. Condensation being caused by the radiation of heat from the pipes, the object is to arrest the radiation, that is, to keep in the heat by inclosing the pipes in the best non-conducting material that is attainable and cheap enough. In order to effect this, the pipe is wound about, first, with asbestos, followed by hair felting, porous paper, manilla paper, finally, thin strips of wood laid on lengthwise, and the whole fastened together by a copper wire wound spirally over all. This is thrust into a wooden log, bored to leave an intervening air-chamber between the pipe and the wood, and of sufficient size to leave from three to five inches of wood covering. The elasticity of the wrappings permits the free expansion and contraction of the pipe, irrespective of the wood log, which is securely anchored and made immovable. The whole is placed in a trench a short distance below the surface, without regard to frost. At the bottom of the trench is laid an earthen tile drain, to carry off any earth moisture; and in order further to insure the continuous dryness of the wood log enclosing the pipe, if desired, 1½-inch plank is fastened around the log, leaving an air space, and the whole is daubed with coal tar, and covered with earth.

Pipes prepared in the manner described have been tested, and it is stated that these tests show that condensation can be reduced to a point that renders the general transmission of steam not only practicable, but profitable; that is to say, that the loss of heat by condensation is under 2¼ per cent. The only actual experiment of which particulars are given, does not furnish so high a result; this experiment was on 1,600 ft. of three-inch pipe, laid on a descending grade of about 1 in 250, the lower end trapped for water, the steam pressure constantly maintained at 20 pounds at both ends, during 12 hours, and the water of condensation, carefully weighed, amounting to 82 pounds per hour, *i. e.*, about .068 pounds of water per square foot of surface of pipe; that is, 66 units of heat per square foot per hour, or 52 units per foot run. The loss of heat from uncovered steam pipes, with steam of 40 lbs. to 60 lbs. pressure, may be assumed, probably, at something between 320 and 380 units of heat per square foot of surface, partly dependent upon the outside temperature. The Holley boilers in this experiment are stated to have evaporated nine pounds of water per pound of coal. Therefore the extra coal required to keep up the loss from condensation amounted to nine pounds of coal, or at the rate of 30 pounds of coal per hour per mile of three-inch pipe. The actual amount of condensation in large pipes is greater than in small pipes, but the relative per-centage per square foot of surface less than in small pipes. It is stated that from experiments and practice, verified in fifteen cities, the most economical pressure to be maintained in the mains, is from 40 to 60 pounds, although in some cities 70 pounds have been used. Experience with large mains is yet limited. The experience of Detroit demonstrates the fact that 60 pounds pressure could be maintained in four miles of 10-inch and 6-inch pipe, against the drafts for power and heat along the line.

In order to counteract the difficulty arising from the expansion and contraction of the pipes, which are subject to extremes of temperature, varying from, say 39° Fahrenheit, and the temperature of steam at, say 60 lbs. pressure, *i, e.*, 307° Fahrenheit, a junction and service box are used. These are placed at convenient intervals along the line, of 100 to 200 feet. The arriving pipe from the boilers is inserted in the service box by means of a nickleplated extension, or telescopic joint, made steam tight by passing through a stuffing box. The departing pipe is immovably attached to the box, so that one end of each 100 feet of pipe is fast, and the other movable—affording free play to the expansion and contraction.

All service-pipes are taken from the junction-box, which is securely bolted to the masonry and anchored to the pipes. The bottom of the box, being placed lower than the pipes, all water of condensation is carried forward and deposited in it; the arrangements for the escape of the condensed water from the steam pipes will be described presently.

At each point of consumption there is a cut-off, under the control of the consumers. The supply pipes from the mains to the houses are 1½ inches in diameter, and within each house ⅜-inch pipes are used. In addition to the cut-off tap from the main, under the control of the consumer, there is a pressure valve or regulator, by means of which the pressure of steam is reduced, and the supply of the building regulated automatically. This is accompanied by two diaphragms of rubber packing, acted upon by weighted levers, and moving two side-valves. The first valve is weighted to 10 lbs., and the second to 5 lbs., or 2 lbs., if required.

When the steam arrives at the first valve of the regulator, it is under a pressure of 60 lbs.; on passing through the first reducing valve, the pressure is reduced to 10 lbs.; it is then passed through a second reducing valve, and the pressure lowered to 5 or 3 lbs.; thence it passes at this uniform pressure through a meter placed above the regulator, for measuring the amount of steam which passes into each house. Unfortunately, I am not in possession of a drawing, or description of these regulating valves or of this meter, sufficiently clear to enable me to explain their action in detail.

The distribution of heat in the apartments is by means of the radiators before mentioned, which are of the ordinary shape, consisting of inch-pipes about 32 inches long, placed vertically, either in a circle or a double row, and connected together top and bottom. The action of these, in enabling the heat to be regulated, has already been explained. The steam, in passing these radiators, becomes condensed into water at 212°. The heat then remaining and the water may both be utilized. In order to effect this, it is conducted in protected pipes, from all parts of the building where steam has been used, back into the basement, through a specially devised trap. Here it may be used as warm water, or it may be used for warming fresh air; in this case it is passed into coils of pipe set in a brick chamber; into this chamber cold air is admitted from outside of the building, as in the air-furnace, and coming in contact wth the coils of pipes containing the hot water, abstracts the remaining heat, and passes up, through the registers into the rooms above, as warm, pure air, while the water, now cold, passes into the tank for future use, if required.

Holley's steam-trap, by which the water of condensation is permitted to escape from the steam pipes, whilst the steam is retained, is a most simple device. The trap is a vertical cylinder, which can be placed either in connection with the junction and service boxes in the mains or in the houses at the bottom of the return pipe from the radiator. In this cylinder a bucket is suspended by means of a lever. This lever is connected with a valve, which leads into an escape-pipe, carried from the bottom of the cylinder. When the end of the lever to which the bucket is attached is in its normal position, the valve is closed; but when this end is raised, the valve is opened. When the condensed water from the steam rises in the cylinder, it causes the bucket to rise and to push up the end of the lever; this opens the valve, and the water below escapes. The bucket falls again, when the water sinks in the cylinder, and closes the valve before the level of the water is sufficiently reduced to allow the steam to follow.

The heat supplied through the agency of steam can, moreover, be utilized for warming water for domestic use. This may be effected, either by passing a coiled steam pipe through a cistern of water, or by turning the steam direct from the steam pipe into a jug or bucket of water, through an apparatus attached to a flexible tube, and resembling the rose of a watering pot, but with very minute holes to prevent noise. The heat of the steam at a low pressure may also be utilized for cooking, stewing, boiling; and vegetables can be cooked with the steam at the pressure at which it is supplied for warming purposes. But to *brown* meats, *broil* beefsteak, and form the crust of bread, requires a temperature of not less than 300° to 420°, being an amount due to a steam pressure varying from 60 pounds to 350 pounds.

Steam ovens have have been long in use. Mr. Loftus Perkins brought a steam oven for baking bread to the notice of the Government during the Crimean War, and cooking by this means has attained considerable development. But for this, steam at a high pressure is necessary.

Mr. Holley states that a stove, invented by Dr. Silsby, superheats the steam for purposes of baking, broiling and roasting. This stove is made of iron, encased in wood, with single and double ovens, and of various styles. The ovens and top are used precisely as in other stoves. The stewing, boiling and cooking of vegetables is conducted with the steam at low pressure; but when it is desired to bake, broil, or roast, or heat flat irons, it is only necessary to cut off the communication with the steam-supply pipe, leaving the steam in the oven, and to light an argand gas-burner, or, in the absence of gas, a gasoline or coal oil lamp; and in a short time the steam that already surrounds the ovens at 212° becomes superheated to the temperature desired, as indicated by a thermometer, and the cooking is done in the usual manner as in other stoves and ranges. In order to leave nothing to the ignorant or careless discretion of an attendant, an automatic thermostat is arranged to control and regulate the temperature. Superheating must be resorted to for the purposes named; other culinary and domestic processes can be conducted with the low-pressure steam.

Mr. Holley states that the tests to which this stove has been subjected show that it performs the duty of the best cooking stoves in use, without inconvenience and annoyance, with satisfactory results, and in a short time. For example, the average time for roasting meats by this arrangement of superheated steam is stated to be 12 minutes to the pound. Bakers require 30 to 40 minutes to bake 1¼-pound loaves in ordinary ovens; the superheater bakes 1¼-pound loaves with greater uniformity and certainty. A 2-pound steak is broiled in 8 minutes; mutton chops in 4 minutes; oysters are broiled in 4 minutes; a 12 pound turkey required 2 hours to roast; 8 pounds of roast beef, 1 hour; 1 gallon of coffee, from cold water, 8 minutes; light bisquit or buns, 8 minutes; potatoes were baked in 28 minutes.

I have not seen this cooking stove; but if it as satisfactory as the description implies, it would seem that if combined steam heating were introduced into houses, the occupier of a house would be enabled to dispense entirely with fires in the house, and thus be relieved from all the trouble, difficulty, expense, and dust and dirt incidental to their use.

The cost of the fittings in a house fall, of course, on the consumer. The cost at Lockport is stated as follows:—In a moderately-sized eight-roomed house, the expenses have amounted to about 150 dollars, or a trifle over £30; and in a large house, with more expensive fittings, 500 dollars, or about £100. But in applying this system to houses, it may be observed that the manner of applying the heat may be varied according to circumstances. If desired, fresh air may be heated by means of steam pipes in the basement, and conveyed by ducts in the walls to the various rooms, or radiators may be devised to warm the walls of the rooms, so that the unpleasant effect of cold walls and warm air in a room would be obviated. Coils of pipes might be arranged so as to heat flues, or the steam might be applied to work a fan for the extraction of air, and by these combined means, a ventilation as perfect as, and possessing more regularity than that resulting from open fire places, might be easily insured. These are all arrangements which would necessarily be left to the individual householder to arrange for himself. The heat supply may be utilized for purposes of ventilation, as well as for purposes of warming, with very little difficulty.

In discussing the degree of economy effected by the arrangement, the consideration of the collateral consequent saving of labor must be allowed due weight. In a moderate-sized house the annual consumption of coal will not be less than twenty tons; these are stowed in the cellar, and then carried thence in scuttles, which hold about 28 lbs. each—that is to say, at least 2000 separate coal scuttles full have to be taken to various parts of the house, the ashes brought down again, and much labor devoted to removing the dust, with which an open fire covers the furniture. In a moderate-sized house, the complete use of steam would enable, probably, one female servant to be dispensed with. In artisans' houses, the saving of trouble, by having no fires to attend to, no grates to clean, and no coals to carry, would be of much value. In addition to this, each fire deposits much soot in the chimney, which at regular intervals is pushed up into the air by the chimney-sweep, and thus distributed through the neighboring houses, rendering continued cleaning necessary, and compelling a large annual outlay in repainting and re-decorating. There is also a great inconvenience to street traffic, caused by distributing coals to every house in every street.

The published reports do not furnish any satisfactory data by which the economy of the system can be tested relatively to other methods of heating. The following facts, however, are taken from the published reports. When the Holley Steam Combination Heating Company commenced operations at Lockport, in 1877, in the absence of all previous experience as to the cost of manufaaturing and distributing steam, the company supplied heat at a price equal to the previous average cost of coal to each consumer, with satisfactory results to all concerned. As an example, the school house measured 105,000 cubic feet of air space to be heated. The average annual cost of fuel, labor, repairs, &c., had been about £130; of these £60 was for the item of coal. The company therefore agreed to maintain a temperature of seventy degrees from 8 o'clock a. m. to six o'clock p. m. for £60, and the warming and the ventilation of the building gave entire satisfaction to the trustees and the pupils. It is stated that experience, thus far, rather tends to diminish than increase the expense of steam heating, and that the company have redueed their charges for heating that school house to £54 per annum.

It was regarded as no small item, by the first year's consumers, to be saved the annoyance of handling coal, ashes, kindling, &c., also the expense of stoves and repairs; but further experiment has led some steam companies to lump their charges for steam at 8s. per thousand cubic feet of air space per annum, which was found to be a still greater economy; but upon the introduction of the meter, made to register about the rate, a further saving might be effected by cutting off radiators in upper rooms, parlors, &c., when not in use, and paying only for the steam actually consumed. Thus, a house of 60,000 cubic feet contents, which is about the capacity of a good class London house, would pay about £24 a year for heat; whilst an artisan, in a model dwelling, which occupies, probably, from 6,000 to 8,000 cubic feet, would pay from £2 4s. to £3 4s. for heat a year, equivalent to from 10d. to 1s. 3d. a week. This is in the United States, where the winters are intensely cold, and where a very considerable amount of heat is necessary during the whole winter. On the other hand, if the steam were paid for by meter instead of by the cubic space, individuals using it might effect a reduction of cost, by cutting off the steam from the radiators in unoccupied rooms.

In Detroit, the company for heating by steam also supplied engines with steam for power. The experience of Detroit, as already mentioned, demonstrates the fact that 60 lbs. pressure could be maintained in four miles of 10-in. and 6-in. pipes, against the drafts for power and heat along the line. The last accounts which the author has seen from Mr. Gordon Lloyd, the engineer of the Detroit Company, states that the company heated a variety of buildings, stores, offices, two banks, one publishing office, one boot and shoe manufactory, &c, belonging to nineteen distinct owners, with an aggregate cubic capacity of 3,300,000 feet, in addition to which it furnished power to eight different establishments, varying from 2 to 65 horse power; in the aggregate, 196 horse power.

The cost last year was about the same as that of private heating, but it would be less on a more extended scale, provided the consumers be not too scattered, necessitating an undue proportion of street main. It is not practicable in cities to return the water of condensation to the boilers, which generally is a great economy, and would be done in all private or isolated cases. Mr. Lloyd, however, considers that the combination of heating with the supply of steam power is not advisable, because, whilst the pressure required for the latter is at least 50 lbs., for heating purposes from 3 lbs. to 5 lbs. would suffice.

If, however, the company which supplied the steam for heating was so located as to be able to supply some factories close to its boilers, and then to apply the steam which had been used for their engines for domestic purposes, considerable advantage and economy might result. And it would be an enormous convenience to a very large number of trades, to shops, to hotels, and to many other places, for a supply of steam to be at hand for working lathes and other small machines, for lifts, and other labor-saving appliances.

The broad principle which the Holley Steam Combination Company has enunciated is that of furnishing heat from a central source of supply, applicable to all domestic purposes, just as gas and water are now supplied; and a list of thirty towns in the United States has been published, in which it is stated that this system is now being applied. It has therefore attained a practical development.

There are, doubtless, many advantages in the open fire-place, amongst which we may class its radiant heat, which warms us whilst it allows us to breathe comparatively cool air; its ventilating power; and the comfort which enables each occupant of a room, by selecting his position, to regulate according to his wishes the amount of heat he derives from it; and no one can feel more strongly than I do how great a loss its abolition would be.

But, on the other hand, with ingenuity and care, it would be quite possible to devise arrangements, in connection with steam heating, which would possess many of the advantages of an open fire; of course, the cheerful blaze could not be replaced; but when it is considered how much our open fire-places do towards polluting the air of a large town with smoke and soot, and all their concomitant evils; when we consider that London which now numbers nearly 4,000,000 of inhabitants, will, at its present rate of increase (a rate which has not varied since the beginning of the century) number nearly 8,000,000 in 1920; when we consider what a vast amount of labor to the community is entailed by the use of an open fire in every room, in the carriage of fuel, the cleaning of grates, and the dirt arising from the air polluted with soot; when we consider that these evils are being daily intensified by the rapid increase of London, and that most of these would be avoided if our supplies of heat were laid on from a central source, we cannot but feel that our advancing civilization, and our large congregations of dwellings, require, therefore, the adoption of some system for the supply of heat, which will enable us to dispense with separate supplies of coal to each house. The Combination Steam-heating system possesses many advantages, and in the rapid extension of houses which is continually taking place round our large towns, it is to be hoped that a trial may be given to the system in this country.

OUR NATIONAL AREA.

By FRANK D. Y. CARPENTER, C.E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

INASMUCH as the geographical extent of a country is in some sense the measure of its importance among nations, it is often desirable to know this area with some approach to accuracy. Searching through gazetteer, geography, encyclopedia, and statistical almanac, the student of political affairs will find the superficial contents of the United States, exclusive of Alaska, variously stated in figures, ranging from 3,000,000 to 3,050,000 square miles. For instance: *Lippincott's Gazetteer* gives 3,002,852, and the *American Cyclopedia*, 3,026,494 square miles. These values are not given in round numbers, as the results of a rough approximation naturally would be, but show an attention to detail which would not do discredit to the estimates for a Nicaragua canal, or to a modern jury's award of damages, and which indicates that precision has been aimed at if not attained.

Such wide discrepancies perplex and astonish the reader accustomed to believe in the infallibility of mathematical processes, and it may not be uninteresting to discuss certain causes which may give rise to these differences. They may result from erroneous methods of computation and measurement of areas; from an ignorance of the geographical position of our territorial outline, owing to a want of accurate surveys; or, what is more likely, from a variance of opinion as to the meaning of the expression, "our territorial outline."

By means of formulas now in use in our Census Bureau it is possible to compute the approximate area of a zone of the earth's surface included between two parallels. If this zone is restricted in width to one degree of latitude, the resulting area is practically correct. It is also found most convenient to limit the length of this belt to one degree of longitude, and thus the unit of surface becomes a square degree. If the country to be measured is a quadrilateral of our spheroidal surface, bounded by two parallels and two meridians, as Colorado and Wyoming, the determination of its area is reduced to the simple process of a summation of the areas of the square degrees contained within its borders. But there are very few political divisions on the face of the earth that are not limited, on one side at least, by an irregular, natural boundary, such as a seacoast, river or mountain range, or perhaps by some arbitrary line of demarkation, as the circular north boundary of Delaware, the geodesic line between Southern California and Nevada, or the traverse separating Connecticut from New York.

In this case it becomes necessary to consult the best maps obtainable, to find how large a portion of each square degree crossed by the boundary is included within it. This proportion of the fractional part to the whole degree, whose area is already known by computation, is easily found by the use of the planimeter: but as this mechanical contrivance is not reliable under certain unfavorable conditions, it should be used with caution and distrust. A safer way is the old-fashioned method of making, from the scale of the map, a reticle of squares on tracing paper, each square a square mile, and counting the spaces embraced in the territory in question. Even then it is generally necessary to apply a correction to the result, as a map is rarely found, even among the best, whose dimensions are not appreciably in error. Owing to faults in construction, the uneven shrinkage and expansion of paper, and to the distortion inevitable in all plane representations of the earth's surface, the length of a degree upon the map measured along the scale is seldom equal to the same degree upon the earth itself, and hence the square degree will be correspondingly too large or too small.

The second source of error is found in the incorrectness of boundary surveys. New and better surveys—later surveys generally are better—by enlarging or diminishing the territory inclosed, tend to invalidate all previous determinations of area. But there is little reason to anticipate any serious change from this cause in the future amount of our national domain. Our perimeter has been so accurately traced by the Coast and Geodetic Survey, the Mexican Boundary Commission, the Lake Survey, and the surveys of the British boundary, both in the north-east and along the 49th parallel, that there is not much room for subsequent fluctuation. The only uncertain gap remaining is the water chain extending from Lake Superior to the Lake of the Woods, and separating Minnesota from the British Possessions. The best maps of this region are probably those which accompany the reports of Professor Hind's explorations in that direction. A more systematic survey, some time in the future, will probably displace this boundary, as now understood, and thus add to or deduct from our national area.

While our country's ambit is so well defined along the British and Mexican borders that any considerable misconception of its position is not excusable, it is quite different along the coast front. The limits of our territory in that direction admit of no precise definition. Some patriots, anxious for the aggrandizement of their native land, would swell its area by counting in that strip of marine territory which skirts the shore and is subject to local jurisdiction, but this, for various reasons, is an extravagant and impracticable claim. In the first place, no one knows how far out to sea a nation's waters extend. There is nothing in foreign treaty or home legislation to establish, beyond dispute, this imaginary boundary of the high seas. Although there is a general impression that, by some kind of tacit international agreement, this limit is placed at three geographical miles from the land, this understanding, if such it can be called, does not even reach the dignity of unwritten law. A truer statement would be that each power, while endeavoring to confine its fellow-nations within a three-mile belt of domestic waters, is inclined to assert its own sovereignty over much greater maritime area, extending its authority as far as permitted by the acquiescence and respect of its neighbors, and very frequently beyond this limit.

In the early part of the present century Russia proclaimed its ownership of all of the North Pacific Ocean above the 51st parallel; although this great gulf was four thousand miles wide at its mouth, the Russian autocrat contended that it was *mare clausum*, because surrounded by his territory on all other sides. In the days of her prosperity, Venice was the Queen of the Adriatic in reality as well as in name. From time immemorial England has held almost undisputed proprietary right to the King's chambers, those concavities of her shore which are hardly worthy of the name of bays, so distant are the headlands inclosing them. To come nearer home, the eminent jurist, Kent, speaking for the United States, reasons that our territory should be considered to embrace all of that portion of the Gulf of Mexico included by a chord reaching from the south point of Florida to the Mississippi River.

It may seem in keeping with the grandiose character of the Spanish people that it should extend its environ of national waters to a width of two marine leagues or six geographical miles. This was exemplified in our recent political imbroglio with Spain, arising from her molestation of one of our vessels off the Cuban coast. and which, as was maintained, was within six miles of the shore. There is, however, a basis of reason in this apparently ostentatious claim. The outer border of a nation's water is a presidial, or garrison line. It has been usually placed at three miles from the shore because that distance was in former times the extreme range of a cannon shot, and a nation's area was supposed to extend seaward as far as could be reached by the strong protecting arm of military power, lodged in a battery or fortress on the land. Now that a cannon ball can be thrown six miles there is no reason why the presidial line should not be located two leagues at sea, as in the case of Spain, with anticipations of a further extension to three leagues with future improvements in artillery.

Thus it appears that the marine possessions of a nation are co-extensive with the arrogance of its pretensions and the range of its cannon, and if it is so barbaric or insignificant as to be deficient in artillery it can make up in arrogance what it lacks in ordnance. Indeed, it has often happened that the most impotent and obscure peoples have been most presumptuous in their pretended sovereignty of the seas. In like manner Selkirk on Juan Fernandez, or Sancho Panza in Barataria, could have issued a proclamation placing his island realm among the first powers of the earth, as regards geographical extent. But such factitious territory, created by edict of king or congress, is as valueless as the fiat money which has no reserve of wealth behind it, and the United States is sufficiently vast in itself to disdain an inflation of its area with any of the waters of the open sea.

Going to the other extreme, there are some purists who would exclude all water, fresh or salt, from our national area. They forget that it is the intermingled water that makes the land valuable and habitable. The streams, lakes, and land-locked bays are as certainly as important a portion of a nation's wealth as an equal amount of solid ground, and are therefore as deserving of representation in that statement of area which we have assumed to be the measure of a nation's importance. If we except the wrecking and life-saving interests, and the proprietors of summer hotels and bath houses, it is difficult to name any direct benefit which accrues to New Jersey from its long stretch of open coast; but a sheltered arm of the sea, such as Raritan Bay, contributes to the welfare of the State in many ways. It is a gateway and outlet for the agricultural and mineral productions of the interior; it is a port of commercial entry and a harbor of refuge in case of storm; it is a quiet and safe fishing ground; and the land itself is not more jealously preserved and guarded than the oyster beds which cover the bottom of the bay, and which are a source of greater revenue than the average agricultural district yields.

The value to our country of New York Harbor is but faintly indicated by the wealth of the cities which surround it, and which are immediately dependent upon it. The Bay of San Francisco has been of far greater service to the State of California than an equal extent of her richest gold fields. The sounds of North Carolina and the lagoons of Florida are useful as inland routes of commerce, and nothing would be gained by substituting in their place the swamps and pine barrens which abound on these coasts. The Mississippi River is but a narrow ribbon of water and yet it would take a very broad belt of cotton land and cornfield to compensate for its absence. Why should we enumerate the thousands of square miles of desert in Utah and leave out the area of Great Salt Lake, by whose beneficent influence a large portion of land otherwise arid is watered and made tillable. Nor is there any good reason for omitting an interior body of water like Lake Michigan from our national area, except, perhaps, that it is convenient to consider the United States as an aggregate of the individual States of which it is composed, and it is difficult to satisfactorily assign Lake Michigan and its tributary, Green Bay, between the two States by which they are enveloped. They can, however, appear under their own names in the list of the component parts of our nation's area, and be accompanied there by Delaware Bay and other extensive boundary sheets of water, whose possession may be disputed by the States which they separate.

If the foregoing opinions are correct the perimeter of a nation's area will coincide with its coast line, but this, unfortunately, is an expression scarcely less indefinite than the presidial line three miles beyond. Until the coast shall be traced by legislation, as it should be, so as to give a well-defined limit to our national waters, the geographer is obliged to rely upon his own judgment in drawing this outline, and, wherever he may locate it, his statement of an area is incomplete if the extent of surface included is not explained in the context or graphically illustrated on an accompanying map. Such explanation and illustration were prepared by the writer to accompany the areas of the States and territories determined by him for the Tenth Census, and will be found in the special bulletin on that subject, issued by the Geographer of the Census, Mr. Henry Gannett. It will be observed that the perimeter of the United States, as indicated by the red line on the map published therewith, includes Lake Michigan, whose area, however, is not given in the column of component parts of the United States, which sums up to 3,025,600 square miles. If to this sum we add the surface of Lake Michigan and Green Bay, which is 22,400 square miles, we have a grand total for the United States of 3,048,000 square miles, which may be adopted as a just and convenient expression for our national area.

In 1794 our Congress intimated a jurisdiction over a certain border of the sea by enacting "that the district courts shall take cognizance of complaints, by whomsoever instituted, in cases of capture made within the waters of the United States, or within a marine league of the coasts or shores thereof," but in neglecting to define "the coasts or shores thereof," it left our maritime boundary as unsettled as before; it is as if a surveyor should locate a station by referring it to some initial point or datum plane whose position was unknown. In a convention between France and England, held in 1839, it was agreed that the coast line, instead of invariably following low water mark, should cross the mouths of all bays and channels not more than ten miles in width. An arbitrary definition like this is not generally applicable, for it is evident that Chesapeake Bay, fifteen miles wide at the mouth and more than one hundred and fifty in length, can more properly be considered a portion of the United States, than some nameless concavity in the shore with a chord of ten miles and a depth of indentation of but two or three.

Many and interesting, and sometimes amusing, are the opinions of the lawyers upon this subject. Referring to the ocean boundary of a country, Lord Hale would have it cross such inlets of the sea as are so narrow that "a man may reasonably discern from shore to shore;" Hawkins agrees with him that this chord should not exceed the range of vision; and Story, more precise, would require this vision to be distinct and with the naked eye. The waters of the United States, mentioned in the Act of Congress lately quoted, would include, according to Wheaton, "the ports, harbors, bays, mouths of rivers, and adjacent parts of the sea enclosed by headlands." Still more liberal, and therefore more unsatisfactory is the statement of Willcock, in his "Ocean, River, and Shore," that "it may be regarded as generally accepted that bays or channels within the horns of promontories and headlands, however large, are subject to the sovereign of the neighboring land." Under the generous terms of this definition, our Atlantic coast would extend in a straight line from Maine to Florida. The makers and expounders of our laws do not seem to realize that there are no straight lines in an ocean shore, but that it is a succession of curves, terminated by capes, and that a chord, from promontory to promontory, may be taken at will from one mile to a thousand miles in length.

While a nation may lose territory from natural causes, such as the subsidence of its shores and the erosion of the banks of a boundary river, there is, on the whole, a greater tendency towards a gain of area, for this increase may result not alone from the upheaval of its coasts and the shifting, in its favor, of a boundary channel, but also, and principally, from alluvial deposits about the mouths of its rivers. By this gradual process the delta of the Mississippi River has been won from the Gulf of Mexico. This invasion of Neptune's dominion is still in progress, as is evidenced by the amphibious condition of the Louisiana coasts, here land and there water, sometimes flooded and sometimes dry. It may puzzle the computer to determine whether to include this disputed belt in the area of the United States, but, looking to the future, when all of this will be habitable ground, it is no more than just to give ourselves the benefit of the doubt, and count it in. This has already been done in the courts of law by Lord Stowell, who once decided that the Louisiana shore, to be accepted as the inner border of our neutral waters, should follow the extreme edge of the islands of debris and the alluvial flats now in process of growth.

Embarrassed by this variety of opinions from the best authorities, it is not strange that the computers of our national area should have disagreed in their results; but due attention being given to the foregoing difficulties, there is little excuse for the remarkably wide range of their wide disagreement. As has been said, the main source of discrepancy will henceforth be found in the adopted position of our national line of *enceinte*, but even here there are certain general principles of guidance in which, it is thought, all will acquiesce. These are that our outline should include half of all boundary rivers and straits; those arms of the sea which are decidedly land-locked, the depth of recess bearing an important ratio to the width of mouth, and especially those bays and harbors which are of advantage to the industries and commerce, and should exclude the great lakes of our northern border, which, in their general conditions, resemble the sea itself. All of these things being considered, however, a perfect coincidence of results, should never be expected, and if two independent determinations of the area of our country, made by geographers of equal judgment and facilities, should differ less than a thousand square miles, their agreement may be accepted as in a great measure fortuitous.

From the total area of the country we derive, by a process of deduction, the contents of the individual States. As the national outline has been much more accurately surveyed than the inter-state boundaries, in the same ratio the area of a single State is liable to have more than its quota of the error affecting the national area. But, by working always by square degrees and fractions thereof, the areas of the States will, in the end, amount to the national area, and the algebraical sum of their errors will thus be restricted in amount to the error of the country at large. Indeed, so little known are some of the boundary lines between our political divisions, that it is quite possible that the error in the area of a single State or territory may exceed the error of the country as a whole. Take, for instance the adjoining territories of Idaho and Montana. They are separated by the Bitter Root Mountains, of whose geographical position almost nothing is known. Some day a good survey will probably displace them by many miles from their present place on our best maps, and will thus correct the areas of these territories by thousands of square miles. But what will be Montana's loss will be Idaho's gain, or *vice versa*, and the national area will remain unchanged.

Until the recent careful determination by the Census Bureau, the published areas of our States and territories have been but little better than traditions, descended from nobody knows where and when. Not more than half of them have approached within a thousand square miles of the truth; but while some have been too large, others have been too small, and thus there has been a partial compensation of error, and the national result has not been so seriously wrong as might have been expected. In all except the latest publications, the area of California is erroneous by thirty thousand square miles. As for Alaska, with its extensive boundaries of unsurveyed coast and unexplored mountain range, it will be very long before an idea can be formed, even moderately approximate, of its geographical extent. With a precision worthy of a better cause, Mr. W. H. Dall makes it 580,107 square miles. Its eastern boundary follows the summit of certain mountains, except where this range is more than ten marine leagues from the coast, in which case it is an artificial line ten miles from the sea. Nothing definite, however, is yet known of the position of these mountains, and we have but little knowledge of the thousands of miles of coast line, a large portion of it in Arctic regions, by which Alaska is inclosed. There is, therefore, room for a probable error of many thousands of square miles in its area, and it would have seemed justifiable in Mr. Dall to drop the odd seven miles from this result, and present his report in round numbers.

It is a fact possessing some interest that a determination of area, made by geodetic computations or by measurements from maps, as herein described, is slightly incorrect, inasmuch as the country to be treated is considered to be at the level of the sea, instead of at its real altitude. A portion of the earth's surface, inclosed by certain meridians and parallels, increases in geographical extent with its distance from the center of the earth, or with its elevation above sea level; it is, in fact, the base of a pyramid whose apex is at the earth's center, and it is evident that the solid angle at the apex remaining the same, the area of the base will increase with its distance therefrom. But all superficial dimensions of the earth are taken at the level of the sea, and are less than they would be if directly measured upon some upland plain, and hence all maps which are constructed by means of these dimensions are correspondingly too small.

This gain, in area, resulting from elevation, is actual and not merely theoretical, and in countries of great altitude it is quite considerable, but it cannot be exactly determined because the mean height of the surface, upon which it depends, can only be roughly estimated. Where the area of a country is found by actual linear measurement along the ground itself, as, for instance, by our land surveys, the result is theoretically correct, but there is such an accumulation of error in the practial workings of a land survey, mile by mile, and acre by acre, that the method of computation is after all more reliable.

The little republic of Switwerland is highly favored in elevation and in consequent gain of area. In our country Colorado, one of the numerous Switzerlands of America, takes rank as the loftiest of our States and territories. According to Mr. Gannett, its mean altitude above the sea is 7,000 feet; while Mr. Louis Nell, author of a recent map of that State, would make it 7,100 feet. As both of these engineers have been engaged for years upon the geographical surveys of Colorado, it is safe to accept a mean of their results, 7,050 feet, or 2,350 yards. The resulting increase of area is seventy square miles, or 44,800 acres.

The United States as a whole, being composed of lower land, does not gain in equal proportion, but adopting Mr Gannett's estimate for its mean altitude, 2,600 feet, it would have about eight hundred square miles more than a corresponding fraction of the earth's surface at sea-level, and consequently more than its area as computed and published.

If the area of a country be defined as the amount of its exposed surface, it will then be increased by the irregularities of mountain and valley which give geological character to the landscape. A mountain has greater surface than a plain, just as the sloping roof of a house has greater area than its floor. It is still a mooted question in some of our agricultural districts whether the man with a hilly farm has more land than his neighbor with a level one. Though he may not have greater acreage, as acres are bought and sold, that is, on a plane basis, yet he really has more surface, and therefore more soil, and, other things being equal, greater productive capacity. The farmer among the hills may find some consolation for the inconveniences of his lot in realizing that, the more numerous the slopes and the greater their angles, the more land does he get for his money.

How much the United States gains from this source could only be considered by speculation at long range, but it may afford a moment's pastime to make a rough estimate for the State of Colorado, which, with its interminable succession of precipitous mountains piercing the sky, and its valley after valley lying deep in the shadows, is especially blessed with this gift of unconsidered area. What even acclivity, then, extending over the entire State, as the roof of a house over its floor, would give an additional area equivalent to that furnished by its numerous mountain-sides, sloping at every angle of the quadrant? Although recognizing the tendency to exaggerate the value of the angle desired, few persons familiar with the serrated profile of Colorado scenery would suggest an incline of less than ten degrees from the horizontal. This would give an additional area of sixteen hundred square miles. An angle of five degrees would result in a gain of four hundred square miles. Taking a mean of these figures it seems safe to say that Colorado is indebted to her mountains for at least one thousand square miles of gratuitous area which has never yet been included in any statement of her geographical extent. Nor is this gain entirely profitless, as some may claim. These are not waste lands by any means. It is the mountain-top—the mother of rain, as the Indians call it—that gathers the snow and stores it for the gradual supply of the streams by which the plains are irrigated; and it is along the mountain-slopes, torn from the bosom of the earth by ancient upheaval and washed by the storms of ages, that her mineral wealth lies exposed.

THE INFLUENCE OF MATHEMATICS ON THE PROGRESS OF PHYSICS.*

From "Nature."

In discussing the value of a given study, a lecturer is by common consent allowed—sometimes even in private duty bound—to exaggerate the importance of his subject, and to present it to his audience enlarged, as it were, through the magnifying power of a projecting lens, so that the details with which he has necessarily to deal may be brought into more prominent view. In an introductory lecture, such as it is my duty to give to-day, the speaker need the less feel any scruples in following the usual custom, as different subjects are treated of in successive years, and the hearer may, after the lapse of a short cycle, strike a pretty fair balance between the various branches which have successively been brought before him. But although I might have felt tempted to-day to insist on the advantages of Applied Mathematics as a separate subject not only worthy of study, but second to none in interest and importance, and though I feel no doubt you would have accorded to me the indulgence which every body requires who endeavors to lay an abnormal stress on the merits of a single branch of human knowledge, I prefer to found the claims of the subject, which I have the honor to represent in this college, not so much on its intrinsic value as on the influence it has had on the progress of other sciences. For no subject can stand by itself, and the utility of each must be measured by

* A lecture, introductory to the Session 1881-82 of Owens College, Manchester, by Arthur Schuster, Ph.D., F.R.S., Professor of Applied Mathematics.

the part it takes in the play of the acting and reacting forces which weave together all sciences into a common web.

The growing importance of mathematics as an aid to the study of all sciences is daily becoming more apparent, and it may indeed be questioned whether at the present time we can speak of physics as apart from applied mathematics. Riemann's opinion that a *science* of physics only exists since the invention of differential equations is intelligible; but however close the connection between physics and mathematics may be or may become, their growth in the earlier stages has been altogether independent. Gallileo may be said to have been the founder of mathematical physics, and amongst his successors have been many who showed a greater inclination towards pure mathematics than towards physics proper. On the other hand, we can trace back the ancestry of our experimental physics and that of our modern popular books on science to the Middle Ages, where we reach J. Baptista Porta and his books on natural magic. Even eighty years ago the fullest account of the state of experimental science was to be found in *Wiegler's Naturliche Magie*, a book of twenty volumes, in which scientific experiments and conjurers' tricks are alternately described. But since the beginning of this century the importance of the mathematical treatment of purely physical subjects has steadily grown, and fifty years ago, the two sciences were already sufficiently united to induce the founders of the British Association to join them together into one section. From that time until the present year, when the mass of work necessitated a temporary separation, the experimentalist and the pure mathematician could be seen at the annual meetings listening, or at least appearing to listen, to each other's investigations, and the influence which men of science on these occasions had on each other may be taken to represent roughly the mutual influence of the two sciences themselves; it was substantial, though in great part unconscious. I could not attempt to-day to give you a complete historical survey of the effect which the contact—one might often say the collision—of the two sciences had on the progress of each; even that part of the subject which I have chosen for special consideration is too vast to be successfully confined within the limits of a single lecture, and an incomplete sketch is all I can offer.

The influence of mathematical investigations on physical theories is not restricted to any single stage, but makes itself apparent throughout the whole course of their evolution. Before a theory is even started, the mathematician is often necessary to prepare its way. He has to classify complicated facts in a systematic manner, and working backwards from the phenomena presented by nature, he endeavors to find out which of them are necessary consequences of others, and which of them require independent hypotheses for their explanation. It is in this way that the works of Poisson, Green, Gauss, and of all those who have followed in their footsteps, may be said to have laid the foundation of the theory of magnetism and electricity, although we do not yet possess any physical notions as to the causes of these phenomena. The true power of mathematics, however, comes into play only when the physical inventor has done his work, and has formed distinct materialistic conceptions, which allow themselves to be expressed by mathematical symbols. It is then that the consequences of the theory are to be worked out and tested by experiment. In order to be convinced of the truth of any hypothesis, the scientific world wants quantitative experiments. Numbers form the connecting link between theory and verification, and they always imply mathematical formulæ, however simple these may be. Often two rival theories are on their trial, and the mathematician is supposed to find out where their conclusions differ and where crucial experiments are most likely to decide definitely between them. It is remarkable, however, how much more often physical or even metaphysical considerations have decided between two theories than arguments derived from mathematical reasoning. So-called crucial experiments, as a rule, come either too early or too late. Sir Humphrey Davy's experiment was absolutely conclusive against the corpuscular theory of heat, but scientific ideas were not ripe yet for the discovery, and his experiment had no marked effect on the progress of science. The crucial experiment here did not involve any mathematical deductions; it is otherwise with that which might have decided between the two theories of light. According to the corpuscular theory, light travels more quickly in water than in air; according to the undulatory theory, the passage through water is the slower, and this distinction is founded on the necessity to account mathematically for the laws of refraction. But when Foucault actually made the experiment, and gave a death blow to the corpuscular theory, that theory was already dead. There was then only one scientific man of note left who still viewed the undulatory theory with suspicion, and his suspicions were not allayed by the crucial experiment. But if mathematical deductions have not decided as often as they might have done between two rival theories, they have constantly strengthened and confirmed our belief in physical hypotheses by inventing new cases which might test the theory, and which might, if experiment supported the mathematical deduction, establish it on a yet firmer basis.

The most important of all the functions of mathematical physics, however, and perhaps the only one through which mathematics has had an unmitigated beneficial influence on the progress of physics is derived from its power to work out to their last consequences the assumptions and hypotheses of the experimentalist. All our theories are necessarily incomplete, for they must be general in order to avoid insurmountable difficulties. It is for the mathematician to find out how far experimental confirmation can be pushed, and where a new hypothesis is necessary. Facts apparently unconnected are found to have their origin in a common source, and often only a mathematician can trace their connection. It is here that the pure experimentalist most often fails. A new experiment gives results to him unexpected, and he is tempted to invent a new theory to account for a fact which may only be a remote consequence of a long-established truth. Many examples might be given to show how mathematics often finds a connection unsuspected by the pure experimentalist, but one may be sufficient. A ray of light passing through heavy glass placed in a magnetic field, in the direction of the lines of force, is doubly refracted as it comes out. To none but a mathematician is it clear that this is only a direct consequence of Faraday's discovery that the magnet turns the plane of polarization of the ray on its passage through the glass. Happily this fact was first worked out theoretically; had it been otherwise, we should have heard much of the power of the magnet to produce double refraction.

In addition to the many services actually rendered by mathematical treatment, the mere attempt to put physical theories into a form fit for such a treatment has often been invaluable in clearing the theory of all unnecessary appendages and presenting it in the simple purity which may bring its hidden failings to light, or may suggest valuable generalizations. Instead of dealing, however, in a general manner with the various ways in which mathematics have been useful in the prosecution of physical investigations, it will be better to give a short account of the growth of some of our physical theories, and to illustrate the subject of this discourse by a few digressions suggested by the historical development.

As a first example I chose the progress of the undulatory theory of light. There is no other branch of physics in which the power of mathematics has been more successfully shown, nor is there one which shows the relations of experimental to mathematical physics in a truer light. At first we had experimental facts ahead of theoretical explanations; then we had the undulatory theory, which placed theory in advance of experiment; and now again a reversal has taken place, and unexplained experiments will remain unexplained until we shall be able to form more definite ideas of the relations between matter and the luminiferous ether.

Huyghens first worked out scientifically the hypothesis that light consisted of the undulations of an all-pervading medium. But as those who adopted the rival theory professed to explain equally well all phenomena which were then generally known, the scientific world preferred to walk in Newton's footsteps, and to reject what they believed to be the complicated and unnecessary assumption of an universal medium. The corpuscular theory could easily explain the ordinary laws of reflection and refraction. Its attempts to explain the colors of thin plates and the fringes of shadows were less successful, but experimental investigations of these phenomena were not sufficiently advanced to bring these facts prominently into view, nor had their true explanation as yet been given. It was only when mathematical analysis was applied to the undulatory theory that its enormous advantages were discovered. Neither of the men to whom we owe the greatest advance which has yet been made in the science of light was a professed mathematician. Young was a medical man, Fresnel was an engineer; nor was the subject, when these men took it up, in a state which would have attracted a mathematician. Conceptions distinctly physical had to be formed, and assumptions not quite satisfactory had to be made. The chief claim to our gratitude rests, not so much on the mathematical treatment they have given, as on the fact that they left the subject in a state sufficiently advanced to allow mathematicians, even without special physical proclivities, to take it up, extend it and establish its foundations more firmly than otherwise they could have done.

The different manners in which Young and Fresnel set to work to prove to the scientific world the truth of their favorite hypothesis, and the corresponding difference in their success is especially interesting for the purpose which we had in view. Both men had considerable mathematical ability, and of the two, Young perhaps had the greater inclination towards pure mathematics, yet he avoided wherever he could the use of mathematical symbols, and disdained to bring forward experimental verification for what he considered sufficiently clear without.* It is to Young that we owe most of the physical conceptions which have secured a final success for the undulatory theory of light. He was the first to explain the principle of interference both of sound and of light, and he was the first to bring forward the idea of transverse vibrations of the undulations of light. The most diverse phenomena were explained by him, but their easy explanation was a sufficient proof to him of the theory he was defending, and he did not trouble to verify his conclusions by extensive numerical calculations. It thus happened, that although Young was first in the field in furnishing the true explanation of complicated phenomena, Fresnel, applying mathematical analysis to a much greater extent, had a much more potent influence in turning the scale of public opinion in favor of their common theory.

Though Fresnel's first memoir was published fourteen years after Young had established the principle of interference, Young's writings had remained unnoticed by him as well as by the scientific world in general, and Fresnel was surprised and irritated to hear that another had been in the field before him. But every one must agree that the chief share in securing the final triumph of the wave theory belongs to Fresnel, nor can there be any doubt that this is due to the mathematical calculations which he applied to cases easily verified by experiment. For there is a great fascination in a table with one column headed "calculated," another headed "observed," and a third giving the differences with the decimal point as much to the left as possible. And it is right that such tables should play an important part in the history of science, for whatever the ultimate fate of a partially accepted theory, the one solid legacy which it will leave behind after its death is the array of numbers, for which in its successful stage it has given a sufficiently correct account.

Fresnel invented different pieces of apparatus to test Young's simple supposition, independently made by him, that waves may be made mutually to destroy one another by addition, the crest of one wave being superposed on the hollow of another. It is necessary that the waves should originally be derived from a single source of light, yet they must seem to diverge from two different points. The necessary experimental conditions were fulfilled by the ingenious device of reflecting the light from two mirrors slightly inclined to each other. The light diverging from the two images of one source was allowed to cross, and bands alternately luminous and dark were

* "For my part it is my pride and pleasure, so far as I am able, to supersede the necessity of experiments."—Peacock's *Life of Young*, p. 477. Abstract letter by Young.

measured at the places where the waves overlapped. A rough micrometer of his own construction served to measure the intervals between the bands at various distances from the mirror, and Fresnel succeeded in obtaining sufficient data to test his theory. It cannot be my purpose to follow Fresnel and to describe all the various devices which he invented to confirm his views, and to establish the true theory of diffraction. Though he succeeded in making a convert of Arago, the greatest authorities then living, and the most influential men in scientific matters, both Laplace and Poisson disdained to consider the theory. The mathematical basis on which the theory rested seemed to them to be weak and insufficient. No doubt they were right; for many assumptions made by Fresnel were daring, and only justified by the results of further more careful investigations; some of his assumptions even were inaccurate. It was only when the phenomena of polarization and double refraction were explained that Laplace acknowledged the great power of the undulatory theory, and with a remarkable inconsistency publicly stated his admiration for Fresnel's work, after a paper which is more unsatisfactory from a mathematical point of view than anything else written by Fresnel. The opposition to the undulatory theory offered by the strictly mathematical school no doubt prevented its rapid acceptance by the general body of scientific men, but it is doubtful whether its final success was delayed. On the contrary, Fresnel was spurred on to greater exertions, and the excitement caused by the violent views taken by the opposed parties rendered the question a burning one, which it was necessary to settle definitely. The impartial observers had, at the time of which we are speaking, one strong argument for suspending their judgment. One great class of phenomena, now known under the title of phenomena of polarization, were unexplained as yet, and it seemed doubtful to them whether the undulatory theory could successfully overcome the difficulty. Then, as before, it was Young who first gave the physical explanation, while it was reserved for Fresnel again to show how the explanation was sufficient to account numerically for all the observed facts.

Those who first started the idea of luminous undulations founded their belief in great part on the analogy between the phenomena of light and those of sound. In a wave of sound each particle moves in the direction in which the waves are propagated, and it was natural to make the same supposition for the waves of light. Yet the mass of unexplained facts forced Young to consider the alternative case of waves in which the motion is in a plane of right angles to the direction of propagation. The waves of water in which such a motion partly takes place may have given to Young the first idea of a supposition which, as he showed, could account for many apparently singular phenomena. But his want of taste for calculations, as well as for experimental verification, prevented him from reaping the full fruits of his fertile ideas. Fresnel tells us that when he first conceived independently the idea of transverse vibrations, he considered the supposition so contrary to received ideas on the nature of vibrations of elastic fluids, that he hesitated to adopt it, and he adds: "Mr. Young, more bold in his conjectures, and less confiding in the views of geometers, published it before me, though he perhaps thought it after me." But when once the question was raised Fresnel applied to it the patient skill which, either by strict mathematical deductions or by happy guesses and assumptions, surmounted all difficulties. The phenomena of double refraction and their connection with polarization were now explained, and all the varied phenomena of light seemed naturally to follow from the simple supposition of waves of transverse vibrations. Such a successful application of mathematical calculations to the investigation of physical phenomena had not been heard of since the time of Newton, and could not fail in the end to produce its due effect. The supporters of Young and Fresnel became more numerous and confident, and the scientific societies duly acknowledged the services rendered by both. Young was elected one of the eight foreign members of the French Academy, and Fresnel received the Rumford Medal of the Royal Society, which, however, only reached him on his death bed.

The undulatory theory now entered on a stage in which it could be taken up by the mathematician pure and simple. Its foundations had to be rendered more secure, and its consequences had to be worked out to a greater extent than even Fresnel had done.

The scruples which hindered most of the French mathematicians from accepting Fresnel's views were shared by Poisson, who deduced from the equations a result apparently paradoxical. According to Fresnel's formulæ, the center of the shadow of a small circular disc formed by a luminous point should be as bright as if the disc were absent. But, however curious this result might be, it had been observed just 100 years before Fresnel's time, and as that experiment had been completely forgotten, Poisson's theoretical conclusion had again to be subjected to the test of experiment, when it was found to be completely in accordance with fact.

But the most remarkable discovery made solely by calculation was the so-called conical refraction, theoretically deduced from Fresnel's wave surface by Sir Wm. Hamilton. That great mathematician had found that a point, when looked at through a crystalline plate cut in a certain direction, should appear not as a point, but as a ring, and the fact was verified experimentally by Prof. Lloyd. This discovery has always been considered one of the greatest triumphs of mathematical physics, and justly ranks on equal terms with the discovery of the planet Neptune by Adams and Leverrier. It is necessary to remark, however, that strange and unexpected conclusions, especially when they have been arrived at after complicated mathematical transformations, tempt us sometimes to exaggerate the additional support which their verification gives to the theory by means of which those conclusions have been reached. It is extremely unlikely that any theory should account for all the facts explained by Fresnel, and not also for all those discovered by his successors. As a matter of fact, Fresnel's wave surface is not the only one which has been suggested, but as they all contain the singular points at which the conical refraction is produced, this phenomenon is no proof that Fresnel's equations are strictly correct. It often happens in mathematical explanations of physical phenomena that the equations orignally deduced contain a series of constants which are then determined to fit the experiments. This process, which is perfectly legitimate, does however often prove only that the theory is successful in giving us a useful formula of interpolation, and need not be conclusive in favor of the ideas which have led to the formula. In a considerable number of cases, such as the reflection of light from metals, and even the theory of double refraction, we have different formulæ which all give, as far as we can test them, a sufficiently correct account of the facts, and none of them therefore prove anything in favor of the views which the different authors of the equations have put forward.

Before leaving our consideration of the services rendered by mathematics to the undulatory theory, we must not forget to notice the mathematical investigations by means of which its foundations have been placed on a safe dynamical basis. The investigations of Cauchy, those of Green, which followed, but especially those of Stokes, have secured for this theory such a firm support that even Laplace might have accepted it without further scruples. As a matter of history these investigations have done little towards the final victory of the theory. They came too late to affect the course of events, but they have increased the confidence of mathematicians in physical theories, and have prepared the way for further investigations.

As I have already remarked, it is one of the great objects of mathematical physics to investigate how far we can safely push certain assumptions and where a new hypothesis must be brought into play. And, indeed, when we have carried our calculations as far as we can, when we have experimented and measured as much as we can, we find that the undulatory theory as it stands at present, though following up to a certain point with marvelous accuracy the true course of nature, shares the common fate of all theories, and leaves a vast quantity of facts unexplained and waiting for more complete investigations. Nor is this to be wondered at; our assumptions as regards materia media may in many cases give correct results, and no doubt answer very well as a first approximation, but we arrive at a point where such a material medium can no longer be considered homogeneous, and here our conclusions must break down; but it is to mathematics that we must look for the next great step. The progress of the science of optics during this century has shown us how much mathematical calculation can help to establish a great and important fact, such as the existence of that all-pervading medium, the vibrations of which constitute light, and I may review more quickly the recent progress of other branches of science.

In the science of heat we do not require mathematical calculations to show the superiority of the mechanical over the corpuscular theory. Sir Humphry Davy's experiment shows conclusively that heat cannot be a substance, and Joule's experiments served further to illustrate the great advantages of the mechanical theory. The mathematical treatment of thermic problems was not required to establish a theory, but was suggested by practical considerations. The important question, how much work we can get out of a steam engine first attracted mathematicians, and out of this question the present science of thermodynamics may be said to have arisen.* Carnot, who gave the initial impulse to these mathematical investigations, assumed in his papers that heat was indestructible, though he seemed personally inclined to prefer the mechanical theory, which denied that indestructibility. Carnot's investigations were only gradually appreciated, and it was only when Clausius and Thomson corrected his theory, so as to bring it into accordance with modern ideas, that general attention was directed to the subject. It was found that so many important consequences of physical interest (as the lowering of the freezing point of water by pressure) followed out of Carnot's corrected reasoning that the mechanical theory now rapidly made its way, and though, as already mentioned, the proof of its truth rests on a perfectly simple experiment, mathematics must be considered to have had an important share in the final establishment of that theory.

It seems impossible to speak of the services rendered by mathematics to the progress of our knowledge of heat without mentioning the great law of the dissipation of energy. No two sciences seem further apart than mathematics and metaphysics, yet mathematical propositions have often furnished material for metaphysical speculations on the workings of nature. Thus the many dynamical propositions involving minimum or maximum properties, such as the principle of least action, have been taken to show that nature always works with the least expenditure of force, and thus the important law of dissipation of energy, which asserts that the world must have a slow and gradual end, could not fail to be used in the discussion of its sudden and abrupt beginning. These metaphysical speculations react again on the progress of physics, but it seems doubtful how far this indirect influence of mathematics has been beneficial; at any rate mathematicians cannot be held responsible for such an extension of their power.

An offshoot of the mechanical theory of heat is the molecular theory of gases. The idea on which that theory is based is not new, but it remained a speculation merely until, chiefly through the labors of Joule, the mechanical theory of heat was experimentally established, and its laws investigated. There is, perhaps, no branch of science in which mathematics has had such unexpected results in forming and confirming our faith in purely physical conceptions. That matter is made up of atoms and molecules is an hypothesis which simplifies many physical and chemical problems. It may, on chemical grounds especially, be considered a highly probable hypothesis, but we could hardly have obtained the confirmation amounting to proof which the idea has received of late years, without the mathematical treatment which it has received at the hands of Clerk Maxwell and those who have followed in his footsteps. One of the most astonishing results obtained by Maxwell is the one subsequently verified by experiment, that so long as Boyle's law is true, the coefficient of viscosity, as well as that of the thermal conductivity in a gas, is independent of the pressure. This fact alone, which could never have been obtained without the aid of mathematics, is a sufficiently strong foundation on

* Foucauld's investigations, though of enormous mathematical importance cannot be said to have had a direct influence on the progress of physics.

which we may rest our belief in molecules. It would be extremely interesting to follow out the more recent developments of the mechanical theory of gases, and to show how both mathematics and the absence of mathematics have advanced its progress, but if it is a good rule to say nothing but good of the dead, it is a better one to say nothing at all of the living.

I have already alluded to the mathematical treatment of electricity and magnetism. The aid of mathematics here was not required to confirm a theory, but rather to prepare the way for one. The complicated laws, regulating the attractions of electric and magnetic bodies, and of bodies carrying electric currents, have by the aid of mathematics been reduced to their simplest form, and electrical units have been connected with the ordinary mechanical units. This interesting branch of physics will furnish us with an example of the services which mathematics has rendered in directing the efforts of experimenters into the proper groove. We need only compare the magnetic measurements which were made during the last century with those made in our own time. While the early investigations gave us only a series of numbers impossible to interpret without a large quantity of accessory data, which are generally omitted, modern measurements, even when made by non-mathematicians, have generally been suggested by mathematical calculations and very often serve a useful purpose.

I have hardly alluded, as yet, to the science of dynamics, which is the foundation of all applications of mathematics. Its progress has been steady since the time of Galileo, but all the marvelous results arrived at by Newton and his followers, results which first showed the great fertility of applied mathematics, are too familiar to need any enumeration from me. The modern researches in hydromatics may perhaps not as yet have led to any definite result of physical interest, but they are rapidly progressing towards that end, and we may look forward to an increasing number of physical discoveries made by the aid of mathematics.

In tracing the history of some of our modern theories, I have followed the usual plan of presenting the history of science as illustrated by the discoveries of our great scientific men. It is necessary however, to draw attention to the fact, and I have tried to keep this point in view throughout this discourse, that it is not always the most conclusive arguments which carry the day, and that second-hand thinkers often had a more potent influence in shaping the course of scientific history than those to whom we now justly ascribe the greater merit of discovery. In our historical studies, therefore, we ought to direct our attention not less to that which has influenced public opinion, than to the actual soundness and originality of each discoverer.

If we ransack old books of science we often come across passages of long-forgotten writings, in which, when they are properly construed, when new meanings are given to old words and obscure expressions are freely translated, we may trace a faint prophetic glimmering of a modern theory. Such passages have a peculiar charm for the student of scientific history; they are often the only reward for much patient and otherwise useless reading, and are interesting as showing the almost boundless ingenuity both of him who made the statement and of him who interpreted its meaning. But those who are fond of this process of exhumation ought not to forget that two parties are necessary to every advance in science—the one that makes it and the one that believes in it, and the course of history is as much affected by the second class as by the first.

"A jest's prosperity lies in the ear
Of him that hears it, never in the tongue
Of him that makes it."

A scientific man, in so far as he influences the progress of science cannot be far ahead of his time, and though his writings may be read and admired centuries after his death, he will have written in vain if he has not been appreciated by his contemporaries or by those who immediately followed. For our present purpose, then, we must consider not so much those mathematical arguments which appear now to us the most conclusive ones, but such as did appear conclusive to those whose opinion they were meant to affect. But if we try to discover what arguments have had the greatest power in removing old prejudices and in causing a solid advance in science, we find that they have often been of the most flimsy nature. Analogies, sometimes not even good ones, have succeeded where solid reasoning has failed, prejudices have been overcome only by other prejudices, and a rough illustration of a point of secondary importance may have made a previously obscure theory look more familiar, though not more clear, to the popular mind. What, for instance, has the existence of Jupiter's four satellites to do with the question whether the earth turns round the sun or the sun round the earth? Yet the discovery of these satellites has produced a greater revolution in favor of the Copernican theory than anything else that Galileo wrote on the subject.

If we look at the history of science from the point of view suggested by these considerations, we find that in addition to the legitimate influence of mathematics which we have traced, its practical effects, through less reasonable causes, have often been as powerful. The statement that in science authority is of no avail against argument, is one the proof of which must be looked for in the future, rather than in the past. There can be little doubt that authority has had a great effect in all scientific revolutions, and the authority of mathematicians was always greater than that of other men of science. Men are thoroughly convinced in one of two ways only; either by a train of reasoning which they can fully appreciate, or by one which is entirely above their comprehension. To those who are particularly amenable to the second kind of proof, mathematics has always been a magic power. Many results first obtained by the help of advanced mathematics have since been deduced by more elementary reasoning, but it seems questionable whether the original author would have been as successful in overcoming the inertia of his contemporaries, if he had confined himself to language intelligible to the greater number of his readers. It is no doubt due to this cause that mathematical papers have brought with them more widespread convincing power than we should now feel inclined to accord to them. The papers of Young, in which he avoided symbols, may appear to us sufficient to establish the undulatory theory of light; the arguments of Sir Humphry Davy, the experiments of Joule, may seem absolutely conclusive in favor of the mechanical theory of heat; but although the mathematical investigations of Fresnel, Clausius, and Thomson could be appreciated only by a much smaller number of readers, they had a more powerful influence in turning the scale of public opinion in favor of the modern ideas. It seems sometimes almost as if it required an experimentalist to convince a mathematician, and a mathematician to convince the general world. It is impossible to enter into greater detail or to exemplify more amply the assertions which I have made without touching on delicate and controversial matters, but on the present occasion it seemed to me to be specially fitting to point out that the course of science is as much affected by the appreciative faculty of receptive minds as by the creative faculty of the discoverer.

It is given to a few only to take an active and successful part in the production of scientific work. The young man who begins life with the idea of making a name as a scientific discoverer is like the little girl in *Punch* who intended to become a professional beauty. They may both be successful, but if so, it will depend as much on the ready appreciation of their contemporories as on themselves. The advance of science takes place through many channels, and each generation has its own part to play. Particular ideas, particular faculties are wanted at particular times, and no one can foretell where success will be. Men who are now quoted as shining lights would have passed away unnoticed had they lived at other times, and many a life has been one of patient but unsuccessful work, because its energies were devoted to a subject which was barren, or at least lay fallow for a time. No one, for instance, who has attempted to read through J. B. Morinus' work (and I doubt whether any one has ever got beyond the attempt) can fail to notice in him qualities which might have made a successful discoverer. In his method of determining longitudes by lunar distances Morinus has left us a lasting legacy. During the greater part of his life, however, his energies were devoted to the study and application of astrology and all the labor spent on that subject was thrown away, although he did his best to make his own prophecies come true, and, having predicted the end of the world for a certain year, went through with his share of the proceedings, and died a natural death at the appointed time. *A priori*, there was no reason why astrology when married to mathematics should not have produced a healthy progeny, and looking especially to the state of science at the time, we can have little fault to find with the old astrologers; it is only the long and sad experience of their failure and disappointment that has given us the right to laugh at their unproductive efforts.

History then does not teach us any royal road to success. But more important for the ultimate progress of truth than a solitary success is the training of the faculty which enables the scientific man to judge correctly, and to appreciate the results of those who strike out new roads and extend the boundaries of knowledge. It seems to me to be one of the chief objects of an institution like this to bring up men, who, by conscientious consideration of scientific speculations, may help to give that solidity and elasticity to public opinion which is necessary for the rapid advance of science.

If I say that the study of applied mathematics is pre-eminently fitted for the improvement of an acute and correct judgment, I only express a sentiment which, I am sure, is felt by each of my colleagues for his own subject. Where so many attempts are made, let us hope, that one may have the desired effect.

THE PRODUCTION AND USE OF GAS FOR THE PURPOSES OF HEATING AND MOTIVE POWER.

By J. EMERSON DOWSON.

From the "Journal of the Society of Arts."

It is hard to realize that so extensive a use of coal gas for illumination has been developed during little more than half a century. Fifty years ago, nearly all towns were lighted, or said to be lighted, with miserable oil lamps, and now the capital publicly invested in works for the supply of gas in the United Kingdom amounts to something like 45 millions; and, for London alone, it is over 13 millions sterling.

The manufacture of lighting gas, on so large a scale, has naturally led to the improvement and cheapening of its production; and this, again, has led to its more extended use for lighting, and to its adoption to a certain extent for heating and motive power. This more general use has led us to become familiar with the advantages of gas as a fuel; but we have also learnt the unpleasant fact that its use for such a purpose is generally attended with much more expense than when coal or coke fires are used. We now know that gas engines are theoretically more efficient than hot air or steam engines, and we know that they cannot burst like steam boilers; but their general adoption is greatly impeded by the high price of the fuel they require.

Ordinary coal gas is also admirably adapted for cooking and innumerable heating purposes, but in the hands of careless persons (and they outnumber the careful ones) it is certainly not economical, compared with coal or coke. Supposing, however, that gas were at such a price that it could be extensively used for fuel, its consumption would be enormous, and as it would greatly reduce the quantity of raw coal used in open grates, the smoke nuisance, from which we suffer so seriously in large towns, would, without doubt, be sensibly abated. We see, therefore, that much may be gained by our having suitable gas at a low cost for heating and motive power, but we have not yet determined how this is to be accomplished. It is, however, a question bearing directly on our health and comfort, and on fuel economy; and as such, it is one of national importance, and therefore deserving of our best attention.

What we really have to do is to consider separately the question of gas for lighting, and of gas for heating; and until this is done, and until we appreciate the principles involved in each case, I fear we shall not arrive at sound and practical conclusions. First, therefore, it will be well for us to remember that, after all, our so-called lighting gas has a very small percentage of illuminating constitutents. Rich Manchester gas has only about 6½ per cent., and ordinary London gas so little as 4 per cent. Roughly speaking, average London gas consists of hydrogen, 52 per cent.; marsh gas, 35 per cent.; carbonic oxide, 8 to 9 per cent.; and olefiant gas, 4 per cent., so that in every 100 cubic feet we have about 96 cubic feet of non-luminous heat giving gases, and only 4 cubic feet of luminous gas. The addition, however, of this small proportion of illuminants adds very greatly to the trouble and cost of preparing the gas, and although this addition is essential for lighting, it is not in the least necessary or desirable for heating purposes.

In the phenomena attending the combustion of lighting gas, the non-luminous heating gases serve to raise the temperature of the carbon particles to a white heat, and it is the incandescent carbon which produces the lighting effect. It is, therefore, consistent with the teaching of science, that there should be a large preponderance of heat giving gas present with the lighting gas, although we have certainly not obtained the best possible proportions in our London gas. We have now to consider what occurs when we use lighting gas for heating purposes, and we shall see that other conditions then obtain. As a matter of fact, when such gas is used as a heating agent, the first thing we almost invariably do is to destroy its luminosity, by the Bunsen, or other atmospheric burners, or blow pipes, used. Here I have a jet of ordinary lighting gas, and if I wish to heat a vessel with it, I cannot let the gas touch the vessel without a deposition of soot, owing to its cooling effect on the flame, and this involves a loss of heat, the soiling of the vessel, and a waste of gas. If I place the gas jet so far under the vessel that the tip of the flame is not in contact with it, I lose much heat, radiated from the sides of the flame, and in cases where a concentrated heat is required, there would also be difficulty in burning the needful quantity of gas. To meet these difficulties, we use a burner, or a blow pipe, which causes a certain quantity of air to mix with the gas before it is ignited. But, as you see, the immediate effect of this is to destroy the luminosity of the flame, for the carbon is brought into such close proximity to the oxygen of the air, and their chemical combustion takes place so rapidly, that apparently there is no intermediate stage of incandescence.

It is true that olefiant gas has a high calorific power, but it is less than that of hydrogen or marsh gas, and it can be well replaced by either of the latter, where heat only is required. We see, therefore, that the presence of the costly illuminating constituents in ordinary coal gas is not only unnecessary for heating purposes, but adds considerably to the difficulty of using it. It then naturally occurs to one to ask, are we right in adhering to the ordinary method of producing gas when required for heating purposes, and cannot other suitable gas be obtained at less cost than ordinary lighting gas? It is my belief that both these questions can be answered in the affirmative, and I will give you my reasons.

In the first place, it has long been established, and is well known, that highly-heating non-luminous gases can be produced by decomposing steam in the presence of incandescent carbon, and it only remains to prove that the process can be carried out in a simple way at a moderate cost. Dr. Siemens was the first to prove to the world on a practical scale, in connection with regenerative furnaces, the great economical and other advantages of using cheap gaseous fuel. This is now matter of history, and his system, or some close imitation of it, has been adopted in all manufacturing countries. In the Siemens gas producer, air only, or air mixed with a small quantity of steam, passes through a mass of red-hot fuel, and gas so made, answers extremely well when used in large quantities, and when highly heated in the regenerative chambers of a furnace. It, however, contains 60 to 70 per cent. of nitrogen, and this large proportion of incombustible gas renders it unsuitable for use in small quantities, as for instance, in ordinary gas burners, or in gas engines, &c. Many other systems have been tried, but it would serve no useful purpose here to describe all that has been done in this direction. Suffice it to say, that the early attempts chiefly consisted of passing steam through iron retorts, charged with carbonaceous fuel, rendered incandescent by external fires. The steam was decomposed, and some of the oxygen combined with the carbon of the fuel, but some of the oxygen also combined with the iron of the retorts, and the process was necessarily abandoned. Messrs. Kirkham introduced the method of decomposing steam by passing it through a column of fuel previously rendered incandescent by an air blast. In this way external fires were dispensed with, and as the retorts could then be lined with refractory material, their oxidation was prevented, and the working cost was considerably reduced. Air was first forced into the generator, until the temperature of the fuel was very high. The air inlet was then closed, and steam was let in. The latter was at first readily decomposed, but at the expense of much heat withdrawn from the fuel; and soon it was necessary to turn off the steam and again introduce the air blast. To make up for the want of continuousness in the process, two generators were worked alternately, and this, and the constant variation in the temperature of the fire, caused serious fluctuations in the quality of the gas.

Many modifications of Messrs. Kirkham's apparatus has since been introduced, but nearly all depend on the intermittent passing of air and steam through the fire. We have already seen that Dr. Siemens has, in some cases, adopted the plan of passing a mixture of steam and air through a fire, and although his gas is weak, it has the advantage of being continuously produced, and of being uniform in quality. In 1875, Mr. J. Kidd patented an apparatus by which he made somewhat similar gas, and a paper on it was read before this Society, in April, 1878. The chief novelty in this apparatus was the placing of a coil round the sides of the gas generator, so that water introduced into the coil might be converted into steam by the heat of the generator fire, the steam thus produced being afterwards passed through the fire, and there decomposed. This answered well when the fire was carefully attended to, but if it was neglected for a short time, wet steam and water passed from the coil, and the apparatus soon became unmanagable. Careful experiments with this gas showed that its calorific power was only 20 per cent. that of ordinary London gas, while the temperature of combustion was also much less than that of the latter.

With your permission, I will now describe briefly the apparatus of which there is a model before you. This model is half the actual size of a generator which produces 1,000 cubic feet an hour. In this system I have imitated Dr. Siemens and Mr. Kidd, in passing a mixture of steam and air through a fire, but I have adopted special means for producing and superheating the steam, and for maintaining all the conditions of working constant and simple, and by so doing, I have sensibly improved the quality of the gas produced. A full-size vertical section of the whole apparatus is shown on the diagram, and from this it will be seen that the steam producer and super heater consists of a long length of tubing bent in such a way as to bring nearly the whole of it over some gas flames underneath. Water, at a pressure of 20 to 25 lbs. per square inch from a town supply, from an overhead cistern, or from a pump with accumulator, is passed into the coil, and there converted into super-heated steam. When the cock regulating the inlet of water has been adjusted, and when the gas has been lighted under the coil, the conditions as to temperature and pressure are constant, and this part of the process needs no further attention. The gas required for heating the coil is drawn from the gas holder, but on the first occasion of starting the apparatus, or whenever there is no gas in the holder, a fire is lighted on a grate under the coil. The retort, or generator, has an iron casing, to make it gas-tight, and this is lined with ganister, as in a foundry cupola, to prevent loss of heat and oxidation of the metal. The fire rests on a grate, and under the latter is a closed chamber, into which a jet of the super-heated steam plays, acting as an injector, and carrying with it, by induction, a continuous current of air. The pressure of the steam forces the mixture of steam and air upwards, through the fire, so that a high temperature of the fuel is maintained, while a continuous current of steam is simultaneously decomposed. In this way the working of the generator is very regular, and the gas is produced rapidly, and without fluctuations in quality. The well-known reactions occur; the steam is decomposed, and the oxygen from the steam and air combines with the carbon of the fuel to form carbonic acid, which is reduced to the monoxide on ascending the fuel column. Approximately, the composition of this gas by volume is, hydrogen 20 per cent., carbonic oxide 30 per cent., carbonic acid 3 per cent., and nitrogen 47 per cent.

Where uniformity of pressure is required, as for engines, burners, &c., or where storage is needed, the gas is passed into a holder. This somewhat retards the production, but the injector causes gas to be made so rapidly that a holder is easily filled when weighted to give a pressure of 1″ to 2″ of water, and at this pressure a generator can pass gas continuously into the holder, while at the same time it is being drawn off for consumption. For boiler and furnace work, the gas can be used direct from the generator, and in such cases, where there is no gas holder, I do not use the super heater above described, but I produce the steam in the gas generator itself. Instead of solid bars for the grate, I use hollow ones, and these I connect together in such a way that the water or steam passes through each bar successively. The heating of these bars is not liable to fluctuations, because the heat to which they are exposed is but slightly affected by any variation in the fuel column above them.

The nature of the fuel required depends on the purpose for which the gas is used. If for heating boilers, furnaces, &c., coke or any kind of coal may be used; but for gas engines, or any application of the gas requiring great cleanliness and freedom from sulphur and ammonia, it is best to use anthracite, as this does not yield condensable vapors, and is very free from impurities. Gas made by this process, and with anthracite coal, has no tar and no ammonia, and the small percentage of carbonic acid present, does not sensibly affect the heating power. A further advantage is, that it cannot burn with a smoky flame, and this is of importance for the cylinder and valves of an engine, and renders it much more easy to apply it to cooking and other stoves than when lighting gas is used. At present, all gas stoves are but compromises, for some of the difficulties attending the use of ordinary lighting gas for cooking and heating purposes are so great, that the makers have failed to overcome them. With a gas, however, which requires little air for its combustion, and which cannot give off smoke or cause a soot deposit, these difficulties nearly all disappear.

About seven pints of water and 12 lbs. anthracite produce 1,000 cubic feet of my gas, but $\frac{1}{10}$th, $\frac{1}{12}$th, and $\frac{1}{15}$th of the gas so made is required to produce and superheat the steam in the A, B, and C sizes respectively of the apparatus used. We have, therefore, an effective production of 900 to about 930 cubic feet, or a mean of, say 915 cubic feet per 12 lbs. of anthracite, allowing 8 to 10 per cent. for impurities and waste. A ton of anthracite produces therefore 170,740 cubic feet, of which about half are combustible.

The cost of manufacture depends to a certain extent on the scale of working, and the figures I am about to give you are unfavorable to myself, because they do not represent working on a large scale, when the expenses would be spread over a large production. No skilled labor is necessary, and in practice, where a single generator is required, it is usual to employ a man who has other work to attend to near the generator, and to pay him a small addition to his ordinary wages. A reliable statement of the actual cost of producing the gas in single generators of the three sizes in use, is given in the following Tables, 1, 2, and 3.

TABLE 1.

Generator A size (producing 1,000 cubic feet per hour).

	s.	d.
Anthracite=12 lbs. × 9 working hours=108 lbs.—or, say 1 cwt. at 15s. a ton..	0	9
Allowance for wages of attendant......	1	0
Repairs and depreciation of generator, gas-holder, &c., 5 per cent. on £125=per working day....................	0	5
Interest on capital outlay...............	0	5
Total.........	2	7

	Cubic feet.
Gas produced	9,000
Less gas used for generating and superheating steam	1,000
Total effective gas for 2s. 7d.	8,000

Net cost, say 4d. per 1,000 cubic feet.

TABLE 2.

Generator B size (producing 1,500 cubic feet per hour).

	s.	d.
Anthracite=18 lbs. × 9 working hours=162 lbs.—or, say 1½ cwt. at 15s. a ton	1	1½
Allowance for wages of attendant	1	0
Repairs and depreciation of generator, gas-holder, &c., 5 per cent. on £140= per working day	0	5½
Interest on capital outlay	0	5½
Total	3	0½

	Cubic feet.
Gas produced	13,500
Less gas used for generating and superheating steam	1,200
Total effective gas for 3s. 0½d.	12,300

Net cost, say 3d. per 1,000 cubic feet.

TABLE 3.

Generator C size (producing 2,500 cubic feet per hour).

	s.	d.
Anthracite=30 lbs. × 9 working hours=270 lbs. at 15s. a ton	1	9½
Allowance for wages of attendant	1	6
Repairs and depreciation of generator, gas-holder, &c., 5 per cent. on £160= per working day	0	6½
Interest on capital outlay	0	6½
Total	4	4½

	Cubic feet.
Gas produced	22,500
Less gas used for generating and superheating steam	1,500
Total effective gas for 4s. 4½d.	21,000

Net cost, say 2½d. per 1,000 cubic feet.

From these Tables it will be seen that, allowing 1s. to 1s. 6d. a day for the proportion of the attendant's time required for feeding the generator, the total cost of production (including depreciation, and interest on capital outlay) is 4d., 3d., 2½d., for the A, B, and C sizes respectively, or a mean of about 3d. per 1,000 cubic feet.

The calculated calorific intensity or the pyrometric effect of London gas of the composition before stated, is 2554° C. (4629° F.), and of my gas 2268° C. (4114° F.) The calculated calorific power of 100 liters of the London gas, or the number of grammes of water which they can raise one degree Centigrade, is 559,038, and of 100 liters of my gas 155,836 grammes. From these figures you will see that 3.5 volumes of my gas are required to give the same calorific power as one volume of the London gas, and therefore we must multiply the cost as given in the tables 1, 2, 3, by 3.5, to give that equivalent of 1,000 cubic feet of the coal gas. Another practical consideration is that coal gas requires 224 to 250 lbs. of coal per 1,000 cubic feet of gas, but my gas requires only 12 lbs. per 1,000 cubic feet; and multiplying this by 3.5, to give the equivalent of 1,000 cubic feet of coal gas, we have 42 lbs. instead 224 to 250 lbs. This is only 16.5 to 18 per cent. of the weight of the coal required for coal gas; and in reference to the cost of transport, this will effect an appreciable saving in many outlying districts.

Although my apparatus is not very large, I cannot, of course, work it in this hall; but I have here a bag of my gas, and I will show you some of it burning. This is an ordinary Bunsen lamp, and before opening the air inlets, I would ask you to notice that when a piece of porcelain or bright metal is held over or in the flame, no soiling or deposition of soot takes place. I will now open the air inlets, and you will see that I can readily heat a piece of platinum, and that notwithstanding the presence of so much nitrogen in the gas, there is very considerable heat energy developed; in fact, the effect produced is very similar to that obtained with coal gas. This can be explained by the fact that one volume of ordinary London gas requires, theoretically, 5.24 volumes of air for its combustion, and yields 61.3 volumes of combustion products at the temperature of ignition, whereas one volume of my gas requires 1.2 volumes of air, and yields, at the temperature of ignition, 18.1 volumes of combustion products. If we then multiply the 18.1 by 3.5, we have a total of 63.3, compared with 61.3, as the volumes in each case, over which the heat of combustion is distributed. I have not gas enough here to make the experiment, but I may mention that I have fused ½ lb. of cast-iron in an ordinary Fletcher furnace of small size.

One of the most convincing proofs,

however, that this gas has considerable heat energy, as well as uniformity of quality, is the fact that it can be used satisfactorily for driving gas-engines. This is no mere opinion of mine, but a fact established by several careful trials made during the past two years, with some of the well-known "Otto" engines. At the Smoke Abatement Exhibition, recently held at South Kensington, my gas has been in daily use for about three months, to drive an "Otto" engine, working a Siemens dynamo-machine, and some Swan electric lights; and the fact that these lights have been uniformly steady is, I think, a good practical proof that the gas is suitable for engine purposes, and that the quality is constant. I may also mention that the English makers of these engines, Messrs. Crossley Bros., Limited, are so satisfied with the suitability and economy of this gas for their engines, that they are now laying down plant to work an aggregate of 200 h.p. with it.

The comparative explosive force of the two gases is as 3.4 to 1, *i.e.*, coal gas has 3.4 times more energy than the Dowson gas. But because the combustion of the carbonic oxide proceeds more slowly than that of the carburetted hydrogen gases, and because the diluents present in the cylinder affect the weaker gas more than the coal gas, in practice with an "Otto" engine, 5 volumes of the Dowson gas are used for one volume of coal gas. Allowing for this, the results of working some 3½ (nominal) h.p. engines have shown that about 110 cubic feet of the Dowson gas are required per indicated h.p. per hour, the indicator diagrams nearly resembling those obtained with coal gas. We have seen that 12 lbs. of anthracite produce 1,000 cubic feet of my gas, and that for the A size apparatus 100 cubic feet per hour are required to produce and superheat the steam used in the generator, so that with this size we have an effective production of 900 cubic feet from 12 lbs. of coal. From this, we see that the above trials, with quite a small engine, have proved that one h.p. indicated per hour is obtained with a consumption of gas derived from 1.46 lbs. of coal, after allowing for impurities and waste of the latter. The "Otto" engines of larger power consume less gas per h.p. than the small ones, and it is not unreasonable to suppose that the result of working the large engines now being prepared for my gas, will be a fuel consumption of very little over 1 lb. per indicated h.p. per hour.

The economical results are important, as you will see by referring to the following Tables, 4 and 5.

TABLE 4.

Working cost of steam engine indicating 35 horse power, for 2,500 hours (50 weeks of 50 hours each).

	£	s.	d.
Coal=35 h.p.×4 lbs. × 2,500=156 2 tons at 15s.	117	3	0
Water at 2 gals. per indicated h.p. per hour=175,000 gals. at 9d. per 1,000.	6	11	3
Oil and waste at 5s. a week×50.	12	10	0
Wages of fireman at 21s. a week×50.	52	10	0
Repairs and depreciation, 15 per cent. on £380, price of engine and boiler fixed	57	0	0
Interest, 5 per cent. on £380	19	0	0
Total	£264	14	3

$\frac{£264\ 14s.\ 3d.}{35\ h.p.}$ = £7 11s. 3d. per indicated h.p. per annum.

TABLE 5.

Working cost of "Otto" engine, with Dowson gas, indicating 35 h.p. for 2,500 hours (50 weeks of 50 hours each).

	£	s.	d.
Dowson gas required=18 cubic feet ×5=90 cubic feet per indicated h.p. per hour ∴ total required=35 h.p. × 90 × 2,500=7,875,000 cubic feet, and anthracite required for 7,875,000 cubic feet+allowance of 875,000 cubic feet for superheated steam=8,250×12 lbs.=44.2 tons at 15s.	33	3	0
Water for making gas, say 8,000 gals., at 9d. per 1,000	0	6	0
Water for cooling engine	0	10	0
Oil and waste at 5s. a week×50	12	10	0
Wages of attendant to feed generator, at 10s. 6d. a week×50	26	5	0
Repairs and depreciation, 10 per cent. on £390 and £170, price of engine and gas apparatus fixed	56	0	0
Interest, 5 per cent., on £560	28	0	0
Total	£156	14	0

$\frac{£156\ 14s.\ 0d.}{35\ h.p.}$ = £4 9s. 6d. per indicated h.p. per annum.

In Table 4 I have given in detail the yearly cost of working a steam engine indicating 35 h.p., and consuming 4 lbs. coal per indicated h.p. per hour, the number of working hours being 50 weeks of 50 hours each. In Table 5, I have given the yearly cost of working an Otto engine with my gas, during the same time, and indicating the same power. This mode of comparison is, to a certain extent, unfavorable to the gas engine; for, in practice, an engine has seldom the same load all day and every day, and, with this class of engine, the governor admits only the quantity of gas required for the actual power to be developed. The gas is in fact bottled up, so to speak, in the holder, and is admitted into the cylinder in the precise quantities required. With steam, however, the boiler fires cannot be regulated to suit exactly the varying power required. In practice, the average power may be taken as about one-third to one-half less than the maximum; but, without allowing for this in any way, and supposing that each engine is working up to a uniform power all the year, we find that the steam engine costs £264 14s. 3d., or £7 11s. 3d. per indicated h.p. per annum, and the gas engine, £156 14s., or £4 9s. 6d. per indicated h.p. per annum. This is an economy of over 40 per cent. in favor of the gas engine, when worked with my gas. Moreover, the saving in weight of coal in favor of the latter, compared with the steam engine is, as 44 to 156 tons = nearly 72 per cent.

I have shown you that this gas can be made very rapidly, and at very low cost, even when produced on a small scale. I have also shown you that it has a considerable heat energy, and that it cannot cause a soot deposit; and I have given you reliable data obtained with actual trials on gas engines. In fact, I have shown you its superiority and great economy, compared with coal gas, for all purposes of heating and motive power, and I think you will, therefore, agree with me, that for factories, large houses, and public institutions, it has many and great advantages.

For the supply of large towns many other considerations obtain, and there is no immediate probability of great changes being made by the companies who have the legalized monopoly of the pipe laying, and whose prosperous condition is against the making of radical changes. I think, however, it may interest you to have a few particulars relating to coal-gas manufacture, so that you may better appreciate the general bearings of the case. In the first place, I would refer you to Tables 6 and 7, which show the total cost of making and distributing gas for the four metropolitan and thirteen suburban gas companies.

TABLE 6.

Statistics of Four Metropolitan Gas Companies for 1880.

Selling price for 16-candle-power gas, per 1,000 cubic feet .... s. 3.39

Total gas sold in year—about 18,091¼ million cubic feet.

Gas sold per ton of coal carbonized—9,529 cubic feet.

Coke made per ton of coal carbonized—44 bushels.

Coke used for fuel—26 per cent. of make,

		Per 1,000 cubic feet sold.
		d.
Cost of coals....................		18.48
	d.	
Less residuals—Coke and breeze...	5.58	
Tar and products............	3.59	
Ammonia and products.......	2.86	
	——	12.03
Net cost of coals...........		6.40
Manufacturing charges:—		
Purifying....................	.91	
Salaries.....................	.41	
Wages (carbonizing)..........	3.58	
Wear and tear................	4.93	
	——	9.83
Working expenses:—		
Distribution.................	2.20	
Rent and taxes...............	1 88	
Management...................	1.30	
Law charges..................	.11	
Bad debts....................	.26	
Public officers, &c..........	.05	
Depreciation of works on leasehold......	.02	
Other charges................	.25	
	——	5.57
Total net cost..............		21.80

Names of Companies.—Commercial Gas Light and Coke, London, and South Metropolitan.

TABLE 7.

Statistics of 13 Suburban Gas Companies for 1880.

Selling price for 14-candle-power gas per 1,000 cubic feet .... s. 4.2

Total gas sold—about 2,310 million cubic feet.

Gas sold per ton of coal carbonized—9,428 cubic feet.

Coke made per ton of coal carbonized—46 bushels.

Coke used for fuel—28 per cent. of make,

	Per 1,000 cubic feet sold.
	d.
Cost of coals	21.19

	d.	
Less residuals—Coke and breeze	6.97	
Tar and products	2.30	
Ammonia and products	2.07	
		11.34
Net cost of coals		9.85
Manufacturing charges:—		
Purifying	.96	
Salaries	.65	
Wages (carbonizing)	4.30	
Wear and tear	5.43	
		11.34
Working expenses:—		
Distribution	1.80	
Rent and taxes	1.91	
Management	3.21	
Law charges	.03	
Bad debts	.24	
Depreciation of works on leasehold	.21	
Other charges	.04	
		7.44
Total net cost		28.63

Names of Companies.—Barnet, Brentford, Bromley. Colney Hatch, Croydon, Crystal Palace, Lea Bridge. Mitcham, Richmond, Tottenham, Wandsworth, West Ham, and Woolwich.

These tables are based on Mr. Field's well-known and carfully compiled analyses of the metropolitan and suburban gas companies' accounts, and I have taken the last year for which these analyses have been published. I have purposely kept the four metropolitan companies separate, because they represent undertakings so huge that certain items of working cost are lower than where the manufacture is on a more moderate scale.

Taking Table 7, which gives the average of thirteen companies, we find that the total net cost of 1,000 cubic feet of 14 candle power gas sold was over 2s. 4½d., after allowing for the sale of residuals, and without including anything for dividends or interest on the capital outlay. We may then ask—"What probability is there of this cost being reduced by further improvements in the present system of gas making?"

I think we may assume that the items given under "working expenses" are not susceptible of much change, and we may as well confine our attention to the other headings. In the weight of coals, and in the wages for carbonizing, it is probable that some saving will be effected when cheap generator gas is used for heating the retorts, instead of the present coke fires. It is also possible that the prices realized for about half of the residuals, *i. e.*, for the tar and ammonia, may increase as new discoveries are made affecting their chemical treatment. But after fully allowing for these, we are then forced to the conclusion that, except in localities specially favored, there is no probability of large reductions being made in the present cost. We have, however, seen that there is a growing need for much cheaper gas for heating and motive power, and my own belief is that this need will not be satisfied until we have an abundant supply of gas for such purposes at 1s. per 1,000 cubic feet. To obtain this, however, I also think that the present system of gas making will have to be departed from.

At the meeting of the British Association of Gas Managers, held at Birmingham, in June, 1881, Dr. Siemens gave some interesting particulars of the varying candle power of the gas produced in ordinary retorts, at different stages of the process of distillation. He showed that, during the first and last stages, the gas given off was of inferior lighting power; and that, for about two-thirds of the whole period of distillation, between the first and last stages, the gas given off was of superior lighting power. From this, he argued, that the richer gas should be drawn off separately, and sold as lighting gas, and that the gas made during the first and last periods should be distributed and sold separately for heating purposes. It is with some diffidence that I venture to offer an opinion against so high an authority on these subjects; but I think it right to say that I see an insuperable practical difficulty in carrying out this suggestion. Such a system would depend on the consumption of the heating and lighting gases respectively following exactly the proportions in which each is produced, and how to effect this without serious trouble and complication in the storage and distribution, I fail to see. It was also urged in the discussion which followed, at the above meeting, that the companies would certainly sustain a loss if they continued to manufacture by their present method, and were to sell only two-thirds of their production as lighting gas, and one-third, at a much cheaper rate, as heating gas. Surely it would be simpler and better to make separately, and in distinct apparatus, rich gas for lighting, and the cheapest possible gas, with coke and decomposed steam, for heating and motive power. The production of each kind of gas could then be easily regulated to suit the consumption.

It has further been suggested that when gas is made solely for heating purposes, it need not be purified at all, or very slightly; but I beg to protest strongly against the adoption of such a suggestion. Tables 6 and 7 show us that the cost of purifying gas for lighting is about one penny per 1,000 cubic feet sold, and such a small saving would never compensate for the loss due to the corrosion of metals and the injury to health which would inevitably follow the liberation of sulphur and ammonia compounds.

That gas for motive power will play a most important part in the future is, I think, beyond doubt; and in confirmation of the views I have expressed on this subject, I would remind you of two important statements which have recently received much public notice. In the first place, so high an authority as the Chairman in Council of this Society has told us in his inaugural address that "the average steam engines in use throughout the United Kingdom certainly do not give one twenty-fifth of the energy which may be taken as residing in the fuel they consume." He also referred to the excellent work done by gas engines, and remarked: "There are many temptations to the use of a good gas engine. There s no fear of the boiler blowing up, no fear of its being injured for lack of water, no stoking is needed, hardly any attention is necessary; and having regard to the great requirement for electrical illumination in clubs, theaters, and even in private houses, there appears to be a very large future for this kind of motor." Then Professor Ayrton has recently shown that the internally fired gas engine has a much higher theoretical efficiency than a steam or hot-air engine. He has, however, pointed out that a gas engine, burning illuminating gas, is in the same position as was, a few years ago, an electro motor for which, until quite recently, zinc was the fuel burnt for producing the electricity. In his remarks he said: "If it be possible to manufacture a cheap heat-giving gas, small gas engines driven with such gas, will not only surpass, in economy, steam engines of the same size, but will produce energy at a cheaper rate per horse power than the largest steam engines ever made."

It may be that the demand already existing for heating gas is not sufficient to warrant the gas companies in putting down separate mains, but I feel sure that the question is one of growing interest, and that gaseous fuel will, sooner or later, be one of the important factors in our industrial and domestic arrangements. The apparatus I have described to you this evening is already being used for several manufacturing and other purposes, and for motive power; and it remains to be seen how far the companies who supply gas to towns may find it to their advantage to adopt a modification of the process.

VOLTAIC ACCUMULATION.*

From "The Engineer."

We owe the term voltaic accumulation to M. Planté; we owe the idea of voltaic accumulation to him also. But more than this—we owe to Planté the rich results of a life devoted almost entirely to researches in connection with this subject. M. Planté employs the phrase voltaic accumulation in a double sense—to signify storage, and to signify cumulative effect. It is in this last sense that the term is generally used by M. Planté, and it is to voltaic accumulation in this sense that M. Planté has chiefly directed his attention. One of his principal aims has been to produce, by means of voltaic accumulation, the high tension effects usually obtained from the frictional electrical machine.

When the platinum terminals of a voltaic battery composed of a few cells are

* Abstract of a paper read by Mr. Swan before the Newcastle Chemical Society.

made to dip in acid water, gas in torrents pours upwards from them. If the same platinum poles, dipping in the same acid solution, be disconnected from the quietly but powerfully working battery, and put in connection with the prime conductor and the cushion of a large electrical machine of the frictional type, you may turn the handle by the hour and produce an amount of electricity that would maintain a continuous stream of fire, and yet not a single bubble of gas will rise from the poles. M. Planté makes a few cells—two are sufficient—do the work of charging secondary cells, which, after being charged, are joined in series and made to develop high tension effects. This is chiefly the kind of accumulation performed by M. Planté by means of his secondary cell, namely, the accumulation of tension or electro-motive force. The Planté cell consists of two plates of lead rolled together, but separated by narrow strips of gutta-percha. These two lead plates being, to begin with, in the same condition, generate no current when immersed in dilute acid and united through the wire of a galvanometer. But if the couple be for a time connected, the one plate with the anode and the other with the cathode of a voltaic cell, or any other form of electrical generator capable of developing an electromotive force of not less than three volts, the anode plate becomes coated with peroxide of lead. If, then, the secondary cell be detached from the primary cells it will be found to be capable of generating a powerful current of about one fifth more electromotive force than Grove's cell. When it is desired to obtain cumulative effects from a series of Planté's cells a mechanical arrangement is made whereby the plates of the different cells are so connected together that they are in effect one couple; that is to say, all the inner plates are connected together as one plate, and all the other plates are connected together as one plate. Arranged in this manner, if one of the poles of two Grove cells, coupled in series, be connected with the terminal which is common to all the inner plates, and the other pole be connected to the terminal common to all the outer plates, the same change takes place in the 100, or it may be the 1,000 cells as that which takes place in charging a single cell. That is to say, if all the outer plates were connected with the positive pole of the Grove cell, all these plates would be oxidized, and in this condition all the cells may be said to be charged, just as a Grove cell is charged when one puts the nitric acid into it; for the highly oxidized lead of a Planté cell plays exactly the same part as the nitric acid of a Grove cell, and it is also necessary to alter the connection of one cell with another, so as to connect them in series, in order to obtain from them the cumulative electromotive effect due to their number.

Planté has devised a convenient method of making this change in the connections. This apparatus illustrates the arrangement. The cells are arranged in line with a spring projecting upwards from each plate on each side of the line; between these two lines of springs an axle of ebonite runs, with metal bands so inlaid upon it, that when it is in one position all the springs on one side are pressing against a long strip of copper on that side, and all the other springs on a corresponding long string of copper on the other side. In this position the cells are arranged for charging, the two long strips of copper being the two poles. When charging has been effected it suffices to turn the ebonite bar on its axis through a quarter of a circle in order to disconnect the springs from the two long strips of metal mentioned, and to bring them into contact with short strips of copper inlaid and insulated in the bar and crossing it obliquely so as to put the oxidized or positive plate of one cell in metallic communication with the non-oxidized plate of the next cell throughout the entire series. The change of connections is the work of a moment, and the result is a muliplication of the electromotive force by the number of the cells.

M. Planté went a step beyond this. He charged a large series of plates of mica, partly coated on each side with tin foil, on the principle of the Leyden jar. These were connected in charging and in discharging in the same manner as the secondary battery, that is, all the coatings of tin foil turned one way were connected together, and all the coatings turned the other way were connected together. When, by the momentary joining of these two groups of plate coatings to the two poles of 800 secondary cells, the plates became charged, the connections were then changed from quantity to tension. By this contrivance the electromotive force of the four volts, due to the two primary Grove cells, was accumulated first to 1,800 volts, and this again was increased fifty fold by the mica plates. I can bear witness to the fact that it was sufficient to produce flashing discharges some inches in length, exactly resembling the discharges of a frictional electrical machine. That is electrical accumulation in one sense, but there is another sense in which the phrase has been much used of late in connection with Faure's accumulator, namely, in the sense of storage. Planté's cell, with slight modifications, lends itself most perfectly to voltaic accumulation in the sense of storage. The very essence of the idea of storage is retentivity. The cell to act as a reservoir or store must be retentive of the charge communicated to it. This is a quality possessed in an eminent degree by the Planté cell. There is, comparatively with other voltaic cells which, but for the want of retentivity, might be employed for electrical storage, very little loss of charge by lapse of time within the limit of a few hours. But for the defect of loss of charge by local action—that is, chemical action not utilizable in the production of electric currents, the zinc and copper cell of Daniell and several other well-known voltaic combinations, not usually regarded as susceptible of being used as secondary cells, might have been employed for electrical storage. Perhaps the ideal of a cell for storage is Grove's gas cell. Here is a specimen of it; it consists of two gas tubes, and two plates of platinized platinum immersed in dilute sulphuric acid. If, while the tubes are filled with dilute acid, one plate is connected with the positive and the other with the negative pole of a voltaic battery, the one tube becomes filled with oxygen and the other with hydrogen, and when so filled the cell is an electric store capable, even after the lapse of a long time, of yielding a current. But Grove's cell is quite out of the question for large operations, if only because plantinum is so scarce. Theoretically it would perhaps be improved by making the hydrogen pole of palladium instead of platinum, so as to obtain the advantage of greater condensation of the hydrogen, and thus to reduce the resistance by increasing the extent of the contact between the gases, the pole plates, and the acidified water. Dr. C. W. Siemens communicated to the York meeting of the British Association some interesting experiments in the employment of plates of carbon, both simple and platinized, as substitutes for platinum plates in the construction of a gas battery. The porosity of the carbon plates was utilized so as to bring the poles close together and greatly reduce resistance. The results obtained were well worthy of publication, although they did not quite reach the point aimed at, namely, practical utility for the electrical storage of energy. For electrical storage on any large scale we look in vain to discover a better material than that fixed upon after infinite painstaking by M. Planté. Planté's cell, pure and simple, is a most admirable electrical accumulator in the storage sense of the word. It has one drawback, however: it requires a considerable time to give to the lead plates a large storage capacity.. M. Planté's method of preparing his cell is as follows:

The secondary cell is first filled with water acidulated with sulphuric acid—1 quart acid to 10 quarts of water—and on the first day it is charged by the current from two Bunsen cells six or eight times, the direction of the primary current being changed at each new charge. The secondary cell is discharged between each reversal of the direction, and it is ascertained either by heating a piece of platinum wire to incandescence, or by other suitable means, that the duration of the secondary current continually increases after each charge. The time during which the secondary couple is submitted to the action of the primary current in the same direction is increased little by little. Thus, on the first day the period is increased from a quarter of an hour to half an hour, and one hour; and, finally, the battery is left over night in the process of charging. The next day it is discharged, and then recharged for two hours in the opposite direction, then again in the previous one, and so on. But soon a limit is reached, beyond which the duration of the secondary current is not found sensibly to increase, especially when the primary cells, not having been removed, have grown by these successive actions little by little weaker, and have no longer sufficient intensity to cause the electrolysis to penetrate deeper into the interior of the lead plates. The secondary couple is then left at rest for eight days, and at the end of that time is recharged in the opposite direction for several hours continuously, without making on that day a fresh alteration in the direction of the primary current. Then the interval of rest is extended little by little to a fortnight, one month, two months, &c., and the duration of the discharge is found to go on continually increasing. It has, in fact, no other limit than the thickness of the lead plates. The positive plate, if it is thin, finishes by being almost entirely transformed by time into peroxide of lead of a crystalline texture; and the negative plate becomes formed by degrees, to a certain depth below its surface, of reduced lead of a granular and crystalline nature. It is not always necessary to push the electrochemical preparations of secondary couples as far as this complete transformation of the physical and chemical nature of the plates, for the couples would ultimately acquire a much greater resistance and take more time to charge them. When the couples yield a current of sufficient duration for the purposes for which one wants them, it is no longer necessary to change the direction of the primary current each time the cells are charged. The quantity of peroxide of lead accumulated upon the positive plate would take too long to reduce, and no result would be got from the couple before several hours. A definite direction is therefore adopted, in which the secondary cells, when once sufficiently "formed," are always charged.

It is evidently desirable—more especially in view of the want more and more urgently felt as time goes on, of an accumulator which will be available for the large and important uses to which electricity will in future time be put—if possible to avoid this tedious process of preparation so minutely described by M. Planté. No doubt it answers the purpose quite well when industrial applications are not in question, but for electrical accumulators such as must be used in connection with a central system of electric lighting, and which would probably involve the use of a set of large cells in every house, this slow process of preparation would be hardly applicable. It was with a desire to avoid this disadvantage and give to Planté's cells a greater capacity of storage that I made the experiments last winter, the outcome of which was the modification of Planté's cell, which I showed you at our February meeting. Here are some of the cells I then exhibited in action. The idea of this modification was to increase the surface of the lead by means of lead foil, crimped and formed into frills, the interstices between the frillings being filled with electrolytically deposited spongy lead. The same idea has been applied in a somewhat different way by M. Faure in his accumulator. In M. Faure's accumulator red lead, mixed with dilute sulphuric acid, is plastered on lead plates, the coated plates are wrapped in felt, and either rolled up like the plates of a Planté cell or doubled together and placed in rectangular lead-lined wooden boxes. These cells have been made on a large scale, and for this reason, and because the application of the red lead coating greatly favors the obtaining of storage capacity, effects have been obtained from them clearly pointing to practical use in electric lighting, and perhaps also for other purposes. The cell has, of course, the same electro-motive force as the Planté cell, of which it is a modification; being large, it has, when fully charged, a small resistance, and is, on that account, capable of producing astonishing effects in the way of heating thick wire. [The lecturer heats some wire.] Thirty of these cells, weighing about 50 lbs. each, when properly charged, will keep twenty of my lamps up to 20-candle power for several hours. M. de Meritens has also made an accumulator on the Planté lines.

I have recently introduced into the construction of the Planté cell some modifications which, I anticipate, will increase its utility when applied on a large scale for the practical work of storage for electric lighting. One of my innovations consists in making the lead plates corrugated or cellular, the cells or grooves being filled with spongy lead, which from the form of the plate will remain attached to it without any external wrapping of felt or similar material being necessary. The felt in the Faure cell must, I imagine, be in a short space of time destroyed by the action of the acid, and occasion displacement of the material applied to the surface of the plate, and held in its position by it. I have heard that it is proposed to substitute asbestos cloth for the felt; this, no doubt, will remedy the defect I have mentioned, but it must greatly increase the cost of constructing the cell. It is obviously desirable to avoid the use of any extraneous material, and the use of grooves or cellular plates accomplishes this object. I have made other improvements for the means of obtaining electrical storage, details of which I must for the present hold in reserve, but with the hope at some future time of bringing them under the notice of the society.

THE ANALYSIS OF POTABLE WATER.

By Mr. CHAS. W. FOLKARD.

A Paper read before the Institution of Civil Engineers.

From "Iron."

In the first place, the author reviewed the present state of analytical chemistry, the conclusion being that, as far as mineral substances were concerned, the existing methods were nearly perfect. But when organic analysis was considered, a different state of things was apparent, owing to the great number, complexity of structure, and unstable nature of many organic bodies, especially those contained in the secretions and tissues of plants and animals, in addition to which organic matter was present in drinking water in very small quantities, and always more or less mixed with other substances.

The subject might be divided into four parts:—(1) The various ways in which water became contaminated; (2) the methods employed by analysts to detect and determine the extent of this contamination, with an opinion as to the probable value of these methods; (3) the bearing of the results of biological and microscopical investigations on the subject; (4) the utility of irrigations, chemical treatment and filtration, for purifying purposes.

Under the first of these heads, the normal constituents of rain water were considered, all of which were practically harmless, so that rain water, as it fell on the earth, or on the gathering grounds of a system of water supply for a town, was unobjectionable, having contracted but an inappreciable amount of contamination. Spring water was not so pure, owing to its percolation through strata from which various mineral substances were dissolved. River water was the most objectionable, on account of the enormous quantities of animal and vegetable contamination which it acquired. Lastly, well water varied greatly in quality, in some cases being excellent where the wells were deep and surface water was excluded, or when the district was thinly peopled; in other instances well water was more contaminated than river water, as in shallow wells in towns.

Under the second heading, the author pointed out that analytical chemists had hitherto been compelled to be content with the examination of the products of decomposition, or with the determination of one or two constituent elements of the organic impurities of water. Unfortunately, the products of decomposition of the organic matter in water were the same as the normal constituents of rain, viz., carbonic acid, ammonia, and nitric acid. It was therefore impossible to ascertain whether those substances were derived from contaminating bodies or had been dissolved by the rain in falling.

The various processes of water analysis were then considered. In the first and oldest method a measured quantity of water was evaporated, and the residue was subjected to a red heat in a platinum dish. By this treatment the animal and vegetable substances were burnt away, and from the loss of weight, the amount of organic matter was inferred. One great objection to this and the following process was the evaporation of the water. With such unstable bodies it was by no means improbable that a large portion was destroyed during the process. By the second method, the solid matter, left after evaporation of a known quantity of the water, was mixed with an oxidizing agent, and heated to redness in a glass tube. The carbon and nitrogen of the organic matters in the residue were obtained in the form of carbonic acid and nitrogen gases, from which were deduced the weight of carbon and of nitrogen present as organic matter in the residue. This ratio of carbon to nitrogen did not, however, afford the slightest clue to the identity of the organic matter. It might be intensely poisonous or dangerous, or, on the other hand, harmless.

The albumenoid-ammonia method consisted in boiling the water with an alkaline oxidizing agent, by which the organic matter was decomposed, and part of its nitrogen evolved in the form of ammonia. This had the great advantage of simplicity of manipulation, and was not open to the objection that previous evaporation was required.

The last considered was the permanganate method. In this the index of impurity was the amount of oxidizing agent—namely, permanganate of potash, required to destroy the organic matter in the water. Inasmuch, however, as no relation had been established between the oxidability of a body and its action on the animal economy, this method would not afford reliable evidence of the fitness of a sample of water for drinking purposes or the reverse.

Under these circumstances the conclusion seemed inevitable, that the subject was as yet beyond the power of the analytical chemist.

It was, however, possible, by the second method, to determine approximately the minimum amount of contamination which had taken place since the water was precipitated as rain. For this purpose the whole of the nitrogen existing in the water was estimated, and the average amount in rain falling on the surface of the earth deducted. The remainder was due to animal and vegetable contamination, and it has been found convenient to express it in parts of average London sewage; that was to say, the sample was returned, as having been contaminated to the same extent as if pure rain water had been mixed with so many parts of ordinary sewage. But this afforded no direct evidence as to its fitness for dietetic purposes, becauses ubsequent oxidation and fermentation might have rendered the water to a great extent harmless

The author next considered the bearing of biological research on the subject, pointing out that mere dilution had an almost inappreciable effect in disarming the germs of disease of their power. Thus, supposing a glass of water to contain but one germ, if the person taking it was sufficiently unhealthy or weakly, he would contract the disease almost as certainly as if there were hundreds of germs. In the author's opinion it would be impossible to banish zymotic disease from towns, the water supply of which contained the dejecta of persons suffering from the disease, even though present in the most minute quantity. The very weakly would contract the complaint from the water, and from them it would spread to the more robust around them. Again, these germs were endowed with such persistent vitality, that they withstood the effects of heat and cold, moisture, drought and chemical agents to an almost incredible extent, affording what seemed, at first sight, indisputable evidence of the now exploded doctrine of spontaneous generation. From this it appeared that once-contaminated water was unsuitable for dietetic purposes.

In conclusion, the author contended that a radical change was the only remedy. Irrigation and chemical treatment were alike powerless; in addition to which, during heavy rain all existing sewerage systems were incapable of dealing with the huge volumes of water poured into them, and the sewage was allowed to flow direct into the river, to the manifest disadvantage of the towns below, who were dependent upon it for their water supply. Filtration, again, was powerless to effect real purification. The germs of disease were so minute that they could pass one hundred abreast through the interstitial spaces of ordinary sand, and dissolved substances were, of course, unacted upon. In view of the great increase in cancerous diseases of the stomach and intestines, the subject was worthy of the most careful study, and taking into consideration the unreliability of the results afforded by chemical analysis, the only way to ascertain if a sample of water was fit for drinking purposes was, in the author's opinion, to trace it to its source, and see that contaminating matter was excluded from the time that the water fell as rain till it entered the reservoir or engine well.

TELEMETERS.

By LIEUTENANT A. H. RUSSELL, U.S.A.

A Paper read before the Society of Arts, Boston.

The object to be accomplished by the use of these instruments is the determination of the distance of an inaccessible object. This is done by measuring the base and two adjacent angles of a triangle. The instruments used vary greatly in construction; that of Berdan, weighing 2000 pounds and costing $5000, has a fixed base of four meters length, and is provided at each end of this base with a telescope, one of these telescopes being set at a fixed angle with the base, and the other capable of being rotated on its axis. The angle made by the line of collimation of the fixed telescope with the base is usually a right angle. The instrument is carried on a two or four-wheeled carriage made for the purpose.

On the other hand, some of these instruments are small enough to be carried in the vest pocket.

He then read an extract from a recent letter by General E. Vray to the London *Times*, to show the importance of the use of telemeters. As will be seen from the following descriptions, the greatest obstacle to the general adoption of range finders is the considerable degree of complexity in their constrtiction, and consequently in their method of use. To use these forms requires skill and a considerable degree of intelligence and information upon the part of the operator. A simple form of instrument readily used by the average non-commissioned officer is required before one can be generally adopted.

Lieut. Russell next divided telemeters into three classes, viz., acoustic telemeters, stadia, and topographical telemeters,—the first depending on the velocity of sound, and the second determining the distance by reference to the apparent height of an object whose real height is assumed to be known.

In regard to the third class, viz., that of topographical telemeters, he said:

As in telemetry, only one side of the triangle to be solved can be known, the problem always reduces to the measurement of a base and two angles. Three cases occur: 1st, the base may be assumed, and the two adjacent angles measured, to fix the direction of the object from the two extremities of the base; 2d, the length of base with one angle at the base can be assumed, and one of the two other angles of the triangle measured; or, 3d, two angles can be assumed, and the length of the base sought, from whose extremities the object can be seen under these two angles; or, in other words, the length of base which subtends the third angle has to be determined.

There are, therefore, three kinds of telemeters, viz.,—

1st, telemeters for variable angles; 2d, telemeters for a variable parallax; 3d, telemeters for a variable base.

Of the first, we know only that of Capt. Nolan of the English army, which effects directly the solution of any triangle whatever.

It measures the two angles at the base, each of which differs only two or three degrees from a right angle.

Two observers are required, furnished with instruments just alike, for working simultaneously at the two extremities of the base.

To determine the distance required in a rapid manner, Capt. Nolan has devised a sort of calculating reel of cylindrical form.

The apparatus complete is composed of the two instruments, of the reckoning cylinder, and of a tape for measuring the length of the base, which varies generally from forty to seventy yards.

Of the second class he enumerated the following, viz., those of Dupuy de Podio, Goulier, Gautier, Klockner, Mariage, Lobbez, Gaumet, and Caillot,—all of which measure the parallax, the right angle and the base being known; also those of Stubendorf, Paschnitz, and Plebani, which measure a segment of the hypothenuse, the right angle and the mean proportional being known.

Of the third class he enumerated (*a*) those of Bauernfeind and Azémar, Nos. 1 and 2, which measure the base, the two angles at the base being known; (*b*) those of Gautier, Bousson, Lobbez, Gaumet, De Roksandik, and Azémar, No. 3, which measure a base, the angle at the base and the angle at the vertex being known; (*c*) that of Bousson, which measures a segment of the hypothenuse, the right angle and the parallax being known.

After a brief description of each instrument he said: Upon the whole, the telemeters used with a variable base have, over those for a variable parallax, the advantage of more simple construction and freedom from all mechanism; they are, therefore, less costly, and less subject to the derangement to which field instruments are exposed. Moreover, they are susceptible of a closer approximation, because the lengths that they measure are directly proportional to the distances; while with other telemeters the angles, or the lengths which represent them, are inversely proportional to the distance. On the other hand, they involve some fumbling about and repetition to fix the angles, which render the operation rather too long, and they often require the measurement of rather long bases, not easily laid off in all localities.

He next divided telemeters into single-station telemeters, or those that carry on the instrument a fixed base, and where the observer has no need to move; and double-station telemeters, where the observer has to take one observation from each station; and said that single-station telemeters are, as yet, far from being suited to field service, and that we must wait before thinking of using them with the army till they have undergone some improvements which science cannot predict. Passing, then, to a consideration of double-station telemeters, he said that the methods of using them reduce in practice to the three following operations:

1st. Laying off a direction which makes a fixed angle, 90° or nearly 90°, with the line to be measured.

2d. Measuring a base in this direction.

3d. Measuring an angle, usually very small, or a length equally small at the extremity of this base.

The first operation is common to all the telemeters. The two others are sometimes combined, so that one of them seems to be suppressed. These telemeters he divided into the following four classes:

1st. Telemeters with crossed telescopes or alidades, among which he enumerated those of Nolan, Dupuy de Podio, Mariage, and Caillot.

2d. Single-reflection telemeters, among which he enumerated, (*a*) those with one mirror, viz., those of Paschnitz, D' Azémar No. 1; and Bousson Porro; (*b*) those with two divergent mirrors, viz., that of D'Azémar No. 2.

3d. Double-reflection telemeters, (*a*) those with two convergent mirrors, viz., those of Gautier, Lobbez, Gaumet, De Roksandik, and Watkins; (*b*) those with three mirrors, viz., those of Bousson and D'Azémar No. 3; (*c*) those with four mirrors, viz., that of Klockner.

4th. Prison telemeters, among which he enumerated those of Goulier, Stubendorf, Plebani, D'Azémar No. 4, Bauernfeind, and similar to this is the Weldon range-finder.

In all the single-reflection telemeters, whether there are one or two mirrors, an angle is laid off by means of the principle that the angle made by the reflected ray of the mirror is equal to that made by the incident ray, and thus, by suitably adjusting the mirror or mirrors, any desired angle can be laid off.

The chief objection to this class of instruments is that the singly-reflected image is very unstable, and any tremulousness of the hand holding the instrument, or any error in the position in which it is held, will cause quite a large error in the distance to be estimated; in other words, the instability of position of the image is a serious objection to their use.

On the other hand, double-reflection telemeters depend for their action on the principle that, when a ray undergoes double reflection from two mirrors, without leaving the plane perpendicular to these two mirrors, the angle formed by the incident ray with the reflected ray is twice the angle of the mirrors. With this arrangement it is evident that the deviation is not changed by the movement of the instrument, so that the principal cause of the instability of the images in the single-reflection telemeters is obviated in the double-reflection instruments. The fixed line of sight might, therefore, be dispensed with, and the mirrors arranged on a plate without enclosing them in a tube, and without eye piece or lateral opening, for it matters little in what part of the mirror one looks. In this case we are exposed to another kind of error; since the steadiness of the image and the constancy of the angle are subject to the condition that the plane of sight, that is the plane fixed by the eye, the mark and the image, shall be perpendicular to the intersection of the mirrors; or, in other words, parallel to the plate carrying the mirrors.

After discussing at some length the double-reflection telemeters constructed with mirrors, he passed to a consideration of prism telemeters. In these instruments two of the faces of the prism serve the purpose of two mirrors inclined at an angle to each other, and the double reflection from these faces makes, with the incident ray, an angle equal to twice the angle these two faces make with each other; moreover, by the use of prisms we obviate the difficulty of having a double image, one reflected from the glass and one from the silvered surface; and also much less light is lost than by the use of mirrors.

One form of the Weldon range finder is a simple glass prism, with two of the faces inclined at such an angle that we should be able to lay off with it an angle of 88° 34′ 3″; for an isosceles triangle, with this for each of the angles at the base, has its sides twenty times the base, hence, if we construct, by the use of such a prism, an isosceles triangle on the ground, whose vertex is at the object whose distance is to be measured, and measure its base, the distance of the inaccessible object will be found by multiplying the base by twenty. In a prism made in London, and sent with a copy of a paper read before the Royal Artillery Institution, by Major J. B. Richardson, and furnished from the ordinance office, the larger angle of the prism was 88° 34′ 3″. This, of course, would not enable us to lay off this angle itself. For this purpose it is necessary that two of the faces should be inclined to each other at an angle of one-half that amount, or 44° 17′ 1.5″. A prism with this angle was made by Mr. Alvan Clark for Lieut. Russell at a cost of $12, but he estimated that they could be supplied in quantity at $2 each.

There was also some difficulty in grinding them accurately to the required angle, but this defect would be removed were a large number required.

Another form of the instrument consists of two mirrors set at an angle of 44° 17′ 1.5″, and this gives similar results.

The first of these instruments involves the same principle as the prisms of Max Bauernfeind, which he has advised for surveying purposes, and which, he says, might be so constructed as to serve for range finders.

The chief difficulties to be met with in the use of such an instrument are the following two: First, when we attempt to lay off an isosceles triangle with fixed angles at the base, it is often difficult, and may be impossible, to find a point at the other end of the base from which the desired object can be seen. In order to overcome this difficulty, it is desirable to be able to have a choice of more than one base; hence, a prism with which we can lay off more than one angle is a desideratum. For this purpose Lieut. Russell proposed to modify Max Bauernfeind's five-sided prism in such a way as to enable one to lay off two different angles by using different faces of the prisms.

It is convenient also to be able to lay off a right angle, and for this purpose two of the faces should be inclined to each other at 45°.

The second difficulty is that, if the observer is to use for both of the base angles of the isosceles triangle the same sides of the prism, he is obliged to move backwards along the base of the triangle. Hence, another improvement is to have a prism by using two faces of which an an angle of a little less than 90° can be laid off, and by using two other faces an angle equal to the supplement of this can be constructed. Whatever the angles at the base be, when the angle of the faces is fixed there is a constant ratio between the side of the isosceles triangle required and the base; and hence, having measured the base, it is only necessary to multiply it by this number to obtain the required distance. In this connection, Lieut. Russell exhibited two pocket-surveying instruments which had been loaned for the occasion by Messrs. Keuffel & Esser, of New York. One of these instruments was an optical square, consisting of two mirrors set at an angle of 45° to each other, thus enabling the observer to lay off a right angle. By setting the mirrors at 44° 17′ 1.5″ instead of 45°, we should have the means of laying off an angle of 88° 34′ 3″, the angle desired in the Weldon range finder.

The instrument consisted of two prisms set across each other, having angles of 22½°, 45°. and 112½°, this instrument enabling us to lay off angles of 45° and 90°. By altering again the angles of the prism we should have the angle required in the Weldon range finder.

Prof. Lanza, of the Institute of Technology, was the next speaker. He said: Through the kindness of Messrs. Keuffel & Esser, of New York, we have before us two pocket-surveying instruments just shown us by Lieut. Russell. These instruments belong to a class which have not been much used in this country, but which, on account of their small size and lightness, are useful in detail work, where very great accuracy is not required.

The optical square, as has been shown, enables the observer to lay off a right angle, and as this angle is laid off by using the double reflection of the object, there is no instability of the image. Another instrument, and one which is due to Max Bauernfeind, is what is called the Prismenkreuz. It consists of two 45° and 90° triangular prisms placed one over the other in such a way that the hypothenuses cross each other at right angles. Looking into the lower prism, we obtain by double reflection the image of an object, the line joining which with the prism is at right angles to our line of sight; looking directly above, into the upper prism, we obtain the image of an object on the prolongation of this line, and looking directly above these over the prisms we look along a line perpendicular to the above-mentioned line. In short, the Prismenkreuz enables us to lay off angles of 90° and 180°, and it enables us, therefore, to solve all surveying problems which depend for their solution on the construction of these angles.

The cross prism as made by Max Bauernfiend could be employed for the same purposes by using the single reflections; but as these are unstable images it is much more conducive to accuracy to use the double reflections; and as these last are always somewhat fainter than the former, it is sometimes a little difficult to see the doubly-reflected image in the presence of the bright single reflection. This difficulty might be obviated, however, by determining the points of the prism faces where the incident rays are to enter the prism, and where the reflected rays are to emerge, and covering up all other parts of the faces of the prisms. This also gets rid of the reflections from the outer faces. I have not here one of these instruments as they are described by Max Bauernfeind, but through the kindness of Prof. Cross, I have had two 45° prisms mounted in the same manner as in the Prismenkreuz. To get rid of the single reflection in these prisms, I have determined these points and covered the remainder of the prisms with paper.

In a conversation with Lieutenant Russell on this subject, it seemed to us that some advantage would be gained by placing the prisms across each other in a different manner, viz., placing the two hypothenuses parallel to each other, with the vertex of each right angle at the middle of the hypothenuse of the other prism, as this, we think, would enable the observer more readily to avoid confounding the single-reflection and the double-reflection images.

The second instrument, loaned by Messrs. Keuffel & Esser consists was, as stated, of two prisms, each of which has angles of 22½°, 45°, and 112½°, one prism over the other, with the two longest sides in the same plane.

This enables us, as was stated, to lay

out angles of 45° and 90°, and hence to solve all those surveying problems that depend on this for their solution.

In addition to the above-described instruments, Max Bauernfeind has devised some four and five-sided prisms for laying angles of 90° and 180°, and he states that prisms with suitably cut angles might be used as range-finders, but does not describe any special arrangement for that purpose. It seems to me that these instruments are deserving of the attention of the Society, as furnishing the means of doing some surveying work, where great accuracy is not required, by means of small pocket instruments, instead of by the use of a heavy transit or theodolite.

FOUNDATIONS.

By Mr. WILLIAM C. STREET, A.R.I.B.A.

A Paper read before the Civil and Mechanical Engineers' Society.

In bringing this subject forward as a topic of discussion, I would claim that it merits the earnest attention of both engineer and architect. It is often taken as too much a matter of course, and in consequence some of our greatest efforts in construction are brought to grief, and that by the neglect of what is obviously the first essential of all good building; while on the other hand sometimes the most creditable and successful part of our work, and what has cost us most thought and care, is hidden from view, and its importance quite unappreciated, especially by those long-necked geese, who would be most sapient and loudest in condemnation if anything were to go amiss.

I shall not hope to exhaust the subject in a short paper, and not having had experience in every kind of foundation, it is to be desired that you will in the discussion not only attack the paper for what it contains, but also for what it omits. By that means the author will be a gainer as well as yourselves. It were almost needless to say that before dealing with any particular foundation, it would be well to consider and calculate the weight of the wall or work we are going to place upon it, and also whether it will be a steady weight or one subject to vibration.* Almost every substance in nature is capable of supporting some other substance or weight, and given a capacity of sustentation, if ever so little per square foot, it is a simple sum to determine how many square feet will be required to take in absolute safety the weight transmitted. By distributing the weight over a sufficiently large area, almost any soil may therefore be safely built upon, provided that its conditions are of a permanent character. This question of constancy is one requiring more than ordinary forethought. Of course, there are cases in which no one could foresee what was subsequently to take place. I know, for instance, of two churches in the London district which were threatened with destruction by the construction of railways in their vicinity. One is in the south-eastern or Bermondsey district, and many years ago, during the construction of one of the viaducts carrying the Greenwich railway, the contractor opened a large extent of deep foundations, which had to be kept clear of water by incessant pumping. This, of course, underdrained and contracted or lowered the ground in the locality, and several alarming cracks made their appearance in the building. A great outcry was raised by the parochial authorities, and the railway company was threatened with heavy damages, but by judicious procrastination on the part of their agents the dispute was deferred until after the completion of the work, when, the pumping having ceased, the level of the water in the soil gradually rose to its former height, and the cracks nearly closed again, so that, by the aid of neat pointing, the permanent damage was but slight. In the second case, the church was built with quite adequate and apparently deep enough foundations; but seven or eight years afterwards a suburban railway is constructed, passing here in

* The weight imposed on the footings of an ordinary London House, say 60 feet high, with four floors all loaded, is perhaps about 7 tons per square foot, while in St. Paul's Cathedral the greatest strain is 14 tons per square foot.

a cutting over twenty feet below them, and only a few yards off. In this case, the drainage was, of course, permanently lowered, and the eastern end of the church, that nearest the line, showed a decided inclination to part company with the nave. The architect, of course, advised that the right thing to be done, was to underpin to a sufficient depth to insure permanent stability. This heroic and costly sort of procedure was objected to by the penuriously-minded; and one of the churchwardens, a votary of modern science, bethought himself of a cunning worker in metals, who took the matter in hand, and has tied together the ruptured parts in an economic manner with iron bands. Up to the present this has sufficed. I only hope that what was the weaker member may not ultimately pull the stronger with it to destruction, and I would sooner have contributed to good masonry underpinning than to this ingenious artifice. Also, in the case of the destruction of several shops and houses in the Seven Sisters Road about two years since, the disaster was, I believe, clearly proved to have been occasioned by the disturbance of the ground at a dangerous depth close to them for the formation of a sewer, just after they had been erected, and when everything was green and unset. It is, therefore, always wise to carefully consider what possible, if not probable, alterations may take place, altering the condition of the substratum or foundation from that in which it is when you build. I will now proceed to notice several different kinds of foundations, and, so far as I know, the best manner of dealing with them.

Peat Foundations.—In some soils, such as peat, it is often practically impossible to carry your walls down to a sufficient depth to meet with a solid base or foundation, and in such cases you have three courses open to you, either to found on a strong concrete floor spread over a sufficient area, or to use piles, or to use cylinders of iron or brick. If the first course is determined on, you should not only carry your floor all over the surface to be occupied by your buildings, and see that it is constructed so as to be thoroughly sound and homogenous, but take care that the edges extend well beyond the footings of your walls. I believe that the cracks and settlements in buildings, with which I was connected as clerk of works, and constructed on such a foundation, were entirely due to very heavy walls coming close on to the edge of the concrete floor, causing it to buckle and crack, and to settle irregularly as weighted by walls of unequal thickness, &c. Another characteristic of this settlement was the gradual and continued settlement of the heavy corners, and I think the French system of forming a lip on the under side of the edge is a good one, as it tends to keep the substratum within its limits, and makes the concrete floor or foundation into a kind of inverted tray. I consider that the material of your foundations cannot be too strong and homegeneous, but with regard to the superstructure, I would prefer a coursed and bounded or articulated construction, that would, if necessary, yield slightly at the joints and accommodate itself, without fracture, to any slight or unequal settlements during construction. This is the more necessary when the foundation to be got is not of the best. I need hardly refer to the description of concrete to be used in such cases, as that is a subject exhaustively treated of elsewhere. I may mention, however, that though you may make lime mortar too fat, and get a bad mortar at a great expense, you can hardly make your Portland cement concrete too fat. I have heard of concrete being made of remarkably weak proportions, but about 1 of cement to 8 of gravel, broken stone, or ballast, is probably little enough; and I would also recommend everybody using Portland cement to test the strength of each delivery, as it is only by that means they can be sure of the strength of their concrete. In the case of some buildings close to where we now are, they also are floating on peat, and this precarious condition was, I fear, aggravated by putting in the foundations in small sections, and with indifferent concrete. The consulting engineers who were called in deprecated underpinning, and built a retaining wall of concrete on the eastern side, and concrete inverts to some of the basement chambers; but I am greatly deceived if the buildings have not continued settling since this was done, about May, 1878. The Admiralty buildings, at Whitehall, are built on timber piles, and apparently with great success, for I do not remember having noticed any particular settlement about the building. That the ground in that locality is sufficiently lively I can personally testify, for the passage of a two-wheeled cart would make a room in Whitehall Place, in which I used to work, vibrate so much as to frighten those who were unused to it.

Sand Foundations. — In founding work on running sand the utmost care and consideration are needed. I have known one length of wall to be undermined by the pumping out of the sand with the water when putting in the foundations for the next length. The only way in such a case is to make your concrete floor the entire width of your trench and put it in as rapidly as possible, to seal the sides of the trench as well as you can, and to pump out what water comes in from the level of the top of the concrete and not from a sump. In the case of dock works founded on running sand, it is also necessary to consider what, if any, will be the effect produced when the pumping operations necessary during construction are brought to a termination, and the water allowed to exert a varying pressure on the floor of the dock and the foundations of the walls, in accordance with the variations of tide level outside the dock. It is open to us all to be very wise after an occurrence has taken place, in which, perhaps, had we had the direction of matters we should not have done nearly so well as those upon whom the misfortune fell, and in indicating in any case how matters might be improved upon, as seen by the light of what has happened, I do so with all humility, and do not for a moment pretend I should have foreseen or prevented the past. In a recent notorious case the damage to the works did not happen until after their completion, when the water being admitted to and constantly retained in the interior at the level of high water, the pressure downwards and outwards at low water was such that it forced itself through the sandy floor and under and along the line of the lock walls out into the river, sucking with it such immense quantities of silt or running sand as to cause a general undermining and ruin of the dock works. There was, of course, a similar varying pressure inwards from the river during the construction of the works, but the dam at the entrance kept this sufficiently far off to prevent ill effects; when, however, this dam was removed and the distance reduced, the effect of similar pressures outwards was so much greater that in a few weeks the underground passage was established and the catastrophe occasioned. It would not perhaps have happened had the pile apron across the mouth of the lock on the river, or dockside, been driven to a greater depth and sufficiently close and tight together, so as to retard the subterranean flow of water and sand. Apparently only a very little extra force, one way or other, was sufficient to turn the balance from safety to danger. The most eminent engineering advice has been taken with regard to the reconstruction, and the author is unacquainted with the measures proposed; but in his opinion it would be better in such a case that the lock should be longer, and thereby the distance increased between the river and the floor of the dock; also that right across the mouth of the lock, at both river and dock end, two rows of either wood or iron sheet piles should be driven as deep as possible, and the sand between them excavated for some depth and the space filled in with good clay puddle, so as to form two watertight underground walls at each end, and sufficiently remote from each other not to occasion danger. Further, the floor of the dock might be covered with a good layer of clay puddle, as you would do if you were making a reservoir to hold water for supplying towns; and I do not know that engineers have any reason for altering this practice when you build a reservoir to hold water and ships, if the natural foundations are not water tight. While speaking of the narrow line between safety and danger, and insisting upon always being on the right side, I would mention the opposite argument taken by an engineer to a Scotch dock not long since. In the carrying out of the work there was a slight mishap, and being remonstrated with by one of the commissioners, the engineer claimed that it proved his ability, because he could well have made the dock cost double the money and then been safe; but he had so designed the work that it was successful, except a slight accident, for little more than half the amount he said a less courageous man would have caused them to expend. Such reasoning can, as has been seen, be followed with disastrous results, and as the foundations are only a small portion of the expense, but the principal portion so far as stability is concerned, you cannot be too safe there.

With regard to foundations for bridges or piers, on or across sands, the usual plan now is to sink iron tubes or piles, with large disc or screw shoes or feet to them, as, by making these feet of suitable diameter, you can adjust your area so as to support any reasonable weight. Mr. Brunlees was the first to use this form of foundation, and by its means carried a railway across the treacherous sands of Morecambe Bay. These sands he found, by numerous experiments, possessed, at a few feet below the surface, a uniform supporting power of about five tons per square foot, if equally distributed, and this was apparently not increased if you went down to a great depth. He sank the piles by means of hydraulic pressure, thereby disturbing the sand at the feet of the piles, and allowing them to sink to the desired depth, when, the pressure being withdrawn, the sand returned to its former consistency and the piles remained stationary.

I will leave, for a moment, the question of character of foundations, and notice the pneumatic process of sinking cylinder foundations under great water pressure. This was, I believe, first introduced by Mr. Hughes in putting in the foundations for Rochester Bridge. In this case the cylinders used were, some of them, 9 feet in diameter, and others 6 feet. The joints of the cylinder were made air-tight, and a wrought iron cover securely bolted to the top. Through this cover two cast iron chambers project, 2½ feet above the top of the cylinder, and 3¾ feet below the cover. These chambers form air locks, one for the passage of men and materials, and the other for buckets containing the stuff excavated. These air locks are furnished with cocks, communicating from the interior of the cylinder to the chamber, and from the chamber to the atmosphere. The cylinders were filled with compressed air at a sufficient pressure to withstand the head of water on the outside of them. To pass into the cylinder, the air in one of the chambers, by means of one of the cocks, is lowered to the pressure of the atmosphere, and whatever is to pass enters the chambers, when the door is closed, and the cock communicating with the inside opened, by which the pressure is gradually raised to that within the cylinder, when you can pass from the chamber into the cylinder. To come out was the same process, reversed. There was a pipe in the form of a siphon, a longer leg of which, reaching to the bottom of the pile, was subject to the pressure of the condensed air on the surface of water within, while the shorter leg, leading into the river, had the effect of relieving the cylinder from any unnecessary or irregular pressure, doing the duty of a safety valve as well as of an outlet for the continual change of air. The greatest depth of the foundations at Rochester was about 61 feet below high water, but in the construction of the foundations of the St. Louis Bridge, in America, on the same principle, part of the work was executed under a pressure of 102 feet of water. When an Act for constructing a railway under the Humber was applied for some years since, the engineer to the promoters designed an ingenious adaptation of this principle. It was proposed to build the tunnel—which was not to be anywhere more than a few feet under the bed of the river—in small sections, using an oblong chamber as a sort of diving bell, excavating the river bed, and building the section within it, and jointing it to the next section by brickwork set in cement under water as the work progresses and the air chamber is raised. The excavation would be in river silt and chalk rock.

Clay.—In carrying out works in the neighborhood of London, we have frequently to encounter what is, especially if on the side of a hill, one of the worst foundations, that of the London clay. If it is in an evil mood, it gives you but short notice. I have known an excavation look as right as possible overnight, and in the morning found the ground had surged in on us, breaking strong timbers as if they were lucifer matches. This soil, as a rule, does not slide or part piecemeal, but seems to wait till the whole mass is of the same mind, and it then comes on you with a quiet and almost irresistible energy. There would appear to be slippery seams in it which contain or allow of the transmission of water, and the upper part will slide forward upon one of these seams, so that if you fairly disturb and set the mass in motion you can easily understand that instead of an ordinary case of angle of repose, it is a hillside with which you have to deal. The only thing is to meet it at right angles, and to disturb as small a section as possible at a time, so that any forward impulse may not be communicated to the mass, and to take care that you have strong cross walls in your basement to act as buttresses. In clay, more particularly, you must be careful to carry your foundations down to or below the ultimate drainage level, as by any subsequent draining of the subsoil it is caused to shrink and is the occasion of ugly and sometimes disastrous settlement. I have been fortunate generally, but in one case, where the money was pinched, I thought we need not carry the foundations of a portion of the building, which was only one story high, down to the depth required for the remainder, where the walls were not only lofty but very thick. The drainage caused by the larger part, which contained a basement, so affected the ground, that the outer corner of the small part with shallow foundations settled considerably. For this the just penalty of underpinning to the proper depth had to be paid. In another case a permanent water level was thought to have been left just half way up the concrete, for at any time during the building, by opening the ground anywhere in the basement, the water would in a few hours rise in the hole to that level, and never above. This looked satisfactory, but within a few months another of those useful and unpleasant metropolitan railway extensions, similar to the one referred to at the commencement, was constructed, with, of course, a drainage considerably below the level I had established. It is, however, some distance off, and the house was also thoroughly well set, and so far no damage has occurred. In this case the walls were asphalted all round up to the ground level, varying from 6 to 12 feet, and by this means the building has been kept eminently free from damp, though nothing can be wetter and colder generally than basements or foundations at that depth in the London clay. In another case, when building the eastern end of a large church on the top of a clay hill, the foundations had to be taken down about 5 feet below those of the adjacent walls, and in which a settlement had taken place some years before, passing from the ground right through the aisle, and also through the clerestory wall right up to the eaves. This looked risky, and under these circumstances I kept the concrete foundation of the new walls at as great a distance as I dare, and then threw up from them an arched underground buttress against the old walls, and built that portion of the new wall upon it. We pointed up the old settlement before commencing, and this has not opened in the least, thus removing much anxiety during the process. Adding to or making a junction with an existing building is, however, always attended with some anxiety, even when the foundations are of the best character. Not only is it well to put up all the walls of a building at the sa me time, and, if necessary, leave the completion of the interior, but it is also far cheaper; more than one building with which I have been connected having cost more from the postponement of portions and being done piecemeal. If you can do no more you ought to make an effort to have the whole of the foundations put in at the same time, so that they at least should be solid and homogeneous. Even then it will be difficult to secure a perfect bond with the teethings left out for you from the old part, as we know that all ordinary brickwork or masonry will settle a little or compress the joints. Some of our best builders, in fact, prefer, because of this, to make a junction by building into a groove or chase cut in the old walls to attempting to bond fresh work into the teeth of the old. With regard to the weight imposed on the foundations, or lower courses, of buildings of any great height or weight, it is also necessary to consider what kind of material you are using, as very recently the tower and the western wall of a church, a short distance from London have had to be underpinned on account of the lower courses crushing, the stone used having been an inferior kind of Kentish rag. It is very seldom you come across so weak a stone, but it is well to know that it is possible to do so. No brick that would be fit to be passed as fit for any part of a good building would be liable to be crushed.

There is one kind of foundation which I have hardly touched upon—viz., timber piles with a strong timber platform on the same. This is a very common foundation in Holland, and generally, when the timber is constantly submerged, it endures for centuries. The supporting power of timber piles is a subject treated of in the office text books for both architects and engineers, and does not need comment from me. This description of foundation is the same as that which used to be employed for bridges across the Thames, but is now generally abandoned, it being considered preferable to take your foundations, cylinder or otherwise, down to the London clay. In the case of Waterloo bridge, the recent improvements, in the shape of embankments, have so increased the scour of the river that the bed is now several feet below some of the timber platforms, and measures are now being taken to strengthen and make good the foundations before they settle, like old Blackfriars. The late Mr. Page proposed a plan, I believe, for putting in cement concrete under existing foundations by means of a spoon and bag, or some such apparatus. Perhaps some member present may be able to explain it to the meeting.

M. Viollet le Duc, in his *Dictionary of Architecture*, states that the ancient Romans always founded their buildings in the most solid manner, by means of large blocks of concrete, composed of quarry rubbish, of gravel, sometimes of burnt earth, and an excellent mortar; this formed under the superstructure homogeneous basements. The Roman foundations are veritable artificial rocks, upon which one could place the most heavy buildings without any fear of rupture or settlements. During the subsequent Roman period the foundations were much neglected, and the architects of the twelfth century had seen so many instances of important edifices falling by reason of bad foundations, and of arches badly buttressed, that they paid particular attention to establish durable foundations, and to render their constructions so elastic that settlements were not to be feared. To them succeeded others, who sometimes, at the request of the ecclesiastical authorities, when means were not plentiful, attempted to make a grand or attractive show of buildings at little expense, and putting in mean and inadequate foundations, occasioned great damage to some most important edifices. Thus periods of good and bad foundations have succeeded each other like tides, or action or reaction.

In conclusion, I can only express my regret that the time at my disposal has really been so small that I feel I have not done the subject justice. I would, however, take the opportunity to urge upon everybody to whom building is entrusted its great importance, and that, though the money to be spent upon the entire work may be small, it is not in the foundations that they should be parsimonious. Let the superstructure or ornamentation be curtailed—they can be extended or attended to later on, when money may be a little more easy; but your foundations once put in, as a rule, have to remain, or, at any rate, do remain in the state in which you finish them, until after a possible catastrophe has happened.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS, 127 East 23d Street, New York—March 15th, 1882. The Society met at 8 P. M., President Ashbel Welch in the chair. The death of Gen. W. W. Wright, member of the Society in Philadelphia, March 9th, 1882, was announced. A paper by Mr. E. H. Keating, City Engineer of Halifax, was read by the Secretary. The paper described the results of the mechanical removal of incrustations from the water pipes of that city. These incrustations had become so serious as to so reduce the pressure that in many places water would not flow from the street hydrants. In some pipes the deposit was over one and one-fourth inches in thickness. Six inch pipes were found reduced to an internal diameter of three and one-fourth to three and one-half inches.

In the years 1875 and 1876 a number of miles of old three-inch pipes were cleaned by a scraper attached to iron rods and propelled by hand. The scraper had four arms or knives attached to a center, and sprung outward by a thick rubber disk. This method was not practically applicable to pipes of large diameter; but in 1880 over a mile of twelve-inch pipe was cleaned by a scraper forced through the whole length by the head of water in the pipe. This scraper was one imported from Scotland. and its work was fairly successful. In 1881 the author of the paper constructed new scraping machines which differed from the others in having additional springs for the cutters and and the pistons. These scrapers consist of an iron rod to which are attached two pistons and two sets of cutting tools, one in front of the the other. The cutters are each made up of four strips of steel two and one-half inches broad sloping backwards from the rod, and at their outer termination shaped and sharpened like the barbs of an arrow. Thus they can yield, when requisite, and the cutting diameter can be altered by moving the steel strips. The pistons are of iron, lead, and leather, to which Mr. Keating adds rubber springs. With this apparatus, and with the ordinary head in the pipes, about twelve miles of 24, 20, 15 and 12 inch pipes were cleaned at a total cost of $2\frac{8}{10}$ cents per foot. The results were remarkably satisfactory, as is shown by the fact that the average pressure on twenty-five hydrants on the wharves steadily increased from $34\frac{8}{10}$ lbs in February 1880, to $52\frac{4}{10}$ lbs in February, 1882. These were on the low service, the source of which is four miles from the city, and 200 ft. above tide. On the high service, the source being eight miles from the city, and 360 feet above tide, there is now a pressure of nineteen lbs per inch at hydrants where the water did not flow at all.

Some remarks were made on the overflow of the Mississippi River by Mr. Lyman Bridges, Member Am. Soc. C. E. The area of the water shed of that river is 1,147,000 square miles, with an annual rainfall of 80,000,000,000,000 cubic feet, and a drainage of 20,000,000,000,000 cubic feet. This is exclusive of the Red River basin. The principal levees are below the Red river. The mean annual amount of sediment passing the mouth of Red river is given by Humphrey and Abbot as 812,500,000,000 tons. The deposit of this at certain points is a source of constant danger. Levees are raised continually, but great floods, as at this time, frequently occur. The speaker suggested as a means of relief, the improvement of the old channel near the mouth of Red river, the improvement of the Atchafalaya and its parallel bayous, a connection with the Mississippi at Plaquemine, and the improvement of the outlet to Atchafalaya Bay. This would give a flood outlet one-half the length of the river from the mouth of Red river, and one-quarter the length from Plaquemine, through which 83% of the present flow could well be carried.

The necessity of complete surveys of the Mississippi was forcibly presented.

ENGINEERS' CLUB OF PHILADELPHIA.—The Secretary presented, on behalf of Mr. Thos. U. Walter, Honorary Member, a description of his experiments in 1836–7, upon the effect of extreme temperatures upon iron bands imbedded in the walls of Girard College, Philadelphia, of which he was the Architect. These bands, each, 54 ft. long, were introduced to resist the lateral pressure of the arches. Although confident that no evil could result therefrom, Mr. Walter considered the positive evidence of these experiments both satisfactory and interesting. The south vestibule wall, 5', 5" thick, subjected to the full power of the sun during summer and in winter under temporary roof, with no fires in furnaces, was selected for experiment. Self-registering thermometers, minimum for winter and maximum for summer experiment, were placed upon the bands and the whole walled in as finished work.

Smeaton's co-efficient of expansion for malleable iron, $\frac{1}{764}$ of length for 180°, being somewhat greater than that of other experimenters, was used. The co-efficient for brickwork, $\frac{1}{1818}$ of length for 180°, was taken from experiments by A. J. Adie, C.E., (Royal Society of Edinburgh, April 20th, 1835).

The difference occasioned by a change of 19° in temperature in a length of 54' is, therefore, less than $\frac{1}{30}$", but if we consider that the exterior of the wall is subjected to the extremes of heat and cold, it will be obvious that the aggregate change of the brickwork is even greater than that of the iron.

Mr. Geo. P. Bland read a paper upon the practical strength of wrought iron columns, giving formulæ and diagram, and arguing that the factor of safety should be established with reference to the limit of elasticity.

Mr. Howard Constable exhibited a blue copy of the Kinzua Viaduct, and stated that its height will be 300' and length 2000'.

Mr. Henry G. Morris described the Hotchkiss Mechanical Boiler Cleaner which consists of a spherical cast iron vessel placed above the boiler, which it enters by a vertical flow pipe bent 90° just below low water line and opening there in funnel form; also by a return pipe carried nearly to the bottom of the boiler. The sediment, rising invariably to the surface before being deposited on the bottom or flues, is carried into the funnel, by the circulation of the water from front to rear of boiler, and reaches the spherical vessel, where it is deposited; the water returning to the boiler by natural circulation. The sediment is removed from the cleaner by opening the valve in a pipe connected with the bottom thereof, after closing the valves in the flow and return pipes.

The Secretary presented a paper by Mr. P. H. Baermann upon "What Thickness of Metal should be given to Cast Iron Pipes under Pressure?" The various formulæ are reduced to the same notation, classified and compared, and illustrated by numerous diagrams. The quality of iron, practical difficulties in casting, minimum strength required for handling, the static head, force of ram and of rapid closing of gates or hydrants and allowance for deterioration, are considered at length. A table of one fifth ultimate strengths is given. One of the main facts derived from the comparison is, that the thickness, obtained from the formulæ, give pipes of varying strength when calculated for a given head, and that the least thickness, necessary to cover imperfections in casting and for safe handling, is ample for pipes of small diameters under all ordinary heads.

ENGINEERING NOTES.

The Channel Tunnel.—Speaking upon the subject of the works in execution for the Channel tunnel at a meeting of the South Eastern Railway Company last week, Sir E. W. Watkin said that certain sensational statements recently made in the press were false, and he was confident that Sir John Hawkshaw had never authorized the statement that he had resigned his position as consulting engineer of the company, because he (the chairman) had proposed a tunnel scheme which did not meet with his approbation. Their tunnel works had been going on for twelve or fifteen months, or longer, during which he had seen Sir John Hawkshaw over and over again, and had never heard a word of objection as to the work at all. Colonel Surtees (a director of the company) had called his attention to the fact that in 1874 it was proposed to make a shaft and sink a tunnel at St. Margaret's Bay, which was about 2¼ miles from the other side of Dover Harbor, or Dover Bay. He (the chairman) referred the question in 1874 to their engineer, Mr. Brady, and the whole matter was gone into. The result was that they strongly protested against the proposal to construct a tunnel beginning at St. Margaret's Bay—first, because it practically excluded them, and secondly, because, according to the best evidence they could obtain, it was impracticable, or so doubtful and expensive that it was next door to being impracticable. After alluding to matters referring only to the shareholders, Sir E. W. Watkin observed that the way to make a tunnel cheaply, quickly, and successfully, was to find the gray chalk at its outcrop and follow it. That was what they were doing, and what, he said, those connected with the scheme eastward of Dover were not doing. The powers they obtained in 1881 enabled them to purchase the foreshore, the land at the back of it, and all the manorial rights attaching to Canterbury Cathedral. They had purchased these rights, which were now the property of the company. It was proposed to transfer a good portion of these rights, as well as the works they had made and the machinery and contracts they possessed to the Tunnel Company. They would themselves complete the works now progressing from the Shakespeare Cliff by the 31st of March, and then hand them over to the other company. The Tunnel Company had associated with them a committee to deal with the various questions arising out of this work. The legal element on the committee was represented by Sir George Bramwell, Sir Edmund Beckett, and Mr. J. F. Moulton; electrical science by Professors Siemens, Preece, and Hughes: as to hydraulic mechanical engineering they hoped to associate with them Sir Joseph Whitworth; civil engineering was represented by Sir James Falshaw, Sir F. Bramwell, C. E., and Mr. William Low, C. E.; Mr. William Spottiswoode (president of the Royal Society), and Professor Boyd Dawkins would give their advice as to geological questions: mining matters would be looked after by Mr. Charles Taylden Wright; military questions would be dealt with by General J. S. Brownrigg, C.B., General Sir Frederick Chapman, G.C.B., and Colonel C. F. Surtees; they would be advised as to tunnel engineering by Colonel Beaumont and Captain English, R.E. In addition to these gentlemen there would be a committee in Paris of distinguished scientific men, who had for years taken an interest in this question. The whole organization was made, and the bargain with the Tunnel Company entered into, subject to the confirmation of the proprietors.

Roads and Road Making.—A member of the Sheffield Highway Committee sends the following remarks on the defective asphalting on the roads and how to improve it to a local paper. He writes:—For many years past I have wished to see a machine introduced into Sheffield for properly mixing and making asphalte, and with that view I have sought after and inspected American, French, German, and foreign machines, none of which, however, complied with the conditions necessary to success, viz., economy, simplicity, cheapness, and non-liability to get out of order. Visiting at Frome, Somerset, I saw a simple machine turning out probably 20 tons per day of the best asphalte ever seen. The raw material was granite, broken into macadam of the size required for road making, and the asphalte for making footpaths was made of the small granite screenings, which was simply barrowed from a Blake's stonebreaker, and thrown into the asphalting machine at one end. In passing through the material was dried and heated by a flue under which was a fire, and on emerging therefrom a tap was turned on from a tar pipe attached, and tar was allowed to run on the hot screenings, a simple worm screw, slowly revolved, conveying and thoroughly intermixing in its passage the asphaltic material. This emptied itself out of the other end of the screw ready for use, at a mere nominal cost, a four-horse engine driving the whole. An engine-tender and two laborers only were required, one to fill and the other to empty the machine. By this process a superior quality of asphalte is obtainable. The granite from the Mendip Hills is of a peculiar carboniferous stratum, and asphalte made from the screenings possesses the property of not being slippery. I am informed neither heat, cold, nor frost affect the surface when made of this extraordinary binding material. I should like to see this cheap and splendid road material introduced and thoroughly tested on our steep inclines, say on the Glossop and Whitham Road, where the poor cab and 'bus horses can scarcely obtain a foothold these frosty and slippery mornings. An enormous saving would result from the use of this economical material; with a small staff of trained laborers and a good, competent foreman, a large surface area of the undedicated roads and footpaths within this borough could quickly be dealt with at a merely nominal cost. Horses are constantly falling on the Ranmoor and Glossop Roads, owing to the present barbarous method of covering over the coal tar macadam asphalte with a fine coating of asphalte, which is a dangerous practice, and few horses in frosty weather can safely travel thereon. Coming down Glossop Road, I note our highway men are laying down asphalte on the roadway, evidently just mixed, which is a pure waste of money, as it will not stand the heavy traffic. It ought to be made and left to toughen by exposure, when it would stand four times as long as when fresh mixed. We ought to keep constantly 20,000 tons in stock ready for use whenever required. By adopting the process above described this could readily be done, and at a fourth of the present cost.

THE HOOGHLY BRIDGE.—It is announced that the long projected railway bridge over the Hooghly is to be taken in hand immediately. A site has been fixed at Chinsura, about 20 miles above Calcutta. The bridge will consist of three wrought-iron girders, each 400 feet long, and strengthened by a curved boom. The cost will be £375,000, and will be borne by the Government. The work will occupy three or four years. When finished, it will enable the East India Railway to run right into Calcutta.

ANOTHER SUBMARINE TUNNEL.—Permission has been granted to the Venetian Society of Construction to carry on the neces sary prel minary works for the construction of a submarine tunnel under the Straits of Messina. According to the plan of the society, the railway line of the tunnel will branch off from that of Eboli Reggio, and, by means of a spiral tunnel, will descend to the level of the submarine line, rising to the level of the Messina Patti line in a similar manner. The approximate length of the submarine tunnel will be 2½ miles. The rock to be traversed is extremely hard, and the thickness of the stratum left between the top of the tunnel and the bottom of the sea will be about thirty meters.

TUNNEL BETWEEN ITALY AND SICILY.—The *Bollettino delle Finanza, Ferrovia e Industrie* states that the Venetian Society of Public Works has asked the Government for authorization to make surveys for a project of railway communication between Sicily and the mainland, by means of a submarine tunnel under the Straits of Messina.

VARLEY'S CONSTANT BATTERY AND CONDENSER.—At the last meeting of the Society of Telegraph Engineers and of Electricians, Mr. Cromwell F. Varley, F.R.S., described a form of Daniell cell patented by him as far back as 1854 (No. 2,555). Curiously enough, this patent has been so far ignored that, according to Mr. Varley, the cells which it describes have been repatented three times, namely, by the late Sir Charles Wheatstone, by Minotti, and by Marie Davy. The cell introduced by Mr Varley to the meeting consists of a glass vessel, in the bottom of which is placed a flat cylinder or box of sheet copper, having its top perforated with holes. This is filled with crystals of sulphate of copper, and an electrode runs from it to the outside of the cell. In the mouth of the cell is suspended a conical knob of zinc, well amalgamated with mercury and having an electrode attached. The conical shape is given to serve the double purpose of allowing the hydrogen gas which is evolved at its surface to rise more freely upward than a flat plate would allow, and at the same time of allowing the metallic copper deposited on the plate to drop more freely off. A solution of one volume of sulphuric acid to one volume of water is the exciting liquid employed; and a layer of porous matter, such as burnt clay, is spread over the drilled hole in the cover of the copper box containing the crystals of sulphate of copper. These crystals dissolve in the liquid and thereby render it heavier than the purer acid solution above. The result is that it tends to remain at the bottom of the cell by its own weight, although this does not prevent diffusion of the copper salt upwards. To prevent the latter as much as possible from reaching the zinc, a siphon is occasionallly inserted in the cell to draw off a portion of the liquid below the zinc, and its place is supplied by fresh acid solution. The amalgamation of the zinc, according to Mr. Varley, insures that the latter will keep the potential due to zinc, however its surface be contaminated by copper or any other metal. Mr. Varley then described the sulphate of mercury battery, which he inserted in his 1854 patent, and which evidently anticipates the well-known Marie Davy cell. It is interesting to note, too, in connection with this patent, that the use of induction surfaces for storing-up electricity for telegraphic and electric lighting purposes is therein claimed. Mr. Varley is a far-sighted inventor, and though the induction surfaces he intends are what are known now as condensers and not "secondary batteries," such as those of Planté and Faure, it is plain that he foresaw some of the service which accumulators of the electric current would render in electric lighting. The induction surfaces were designed by him to "store up the power and so make a small battery answer the purposes of a large one, and also to act as a measure when telegraphing through long submarine cables." They were composed of sheets of tin foil separated by sheets of oiled silk, gutta-percha, or other non-conducting substance, and alternate foils were connected to opposite poles of the battery. Their use in submarine telegraphy is now universal, and they have also been employed by Jablochkoff and others in electric lighting.

RAILWAY NOTES.

RAILWAY SIGNALS.—The railway alarm signal for passengers on the Emperor Francis Joseph Railway, Austria, consists of rods under every carriage, coupled together and communicating by a system of cords and pulleys, with the steam whistle. Other cords, passing round pulleys are attached to the rods, and are led to each compartment, the ends being protected by a frame closed by a sheet of paper. This paper must be burst open before the signal can be given by the passengers.

CONTINUOUS BRAKES ON RAILWAYS.—At the annual meeting of the Amalgamated Society of Railway Servants, last October, in Manchester, it was decided to introduce a Bill into Parliament to compel the companies to carry out the recommendations of the Royal Commission for providing continuous brakes. This Bill is now being prepared, and Earl Delawarr has promised to take charge of it in the House of Lords. In the meantime petitions are being prepared for the signatures of the public and of railway men, urging on both Houses of Parliament the necessity of passing this measure.

Australian Railways and Telegraphs.—The following statistics for the 31st December, 1880, will show the number of miles of railways and electric telegraphs in the various Australian Colonies:

	Miles of railways open and in course of construction.	Miles of telegraph wires.
Victoria	1,213¼	6,019½
New South Wales	1,305½	13,188
Queensland	805	8,150
South Australia	986	6,904
Western Australia	92	1,592¾
Tasmania	172½	1,096
New Zealand	1,466	9,401
Total	6,040¼	46,351

Canadian Railways.—Next session the Parliament will be asked to charter a line between Fort William and Pigeon River, which separates the northeastern corner of Minnesota from Canadian territory. This line is intended to connect with a railway from Duluth to Pigeon River, in aid of which a land grant of over 20,000 acres a mile has been offered by the Minnesota Legislature. The whole distance from Duluth to Fort William by rail would be a trifle over 200 miles. The Leamington and St. Clair Railway Company has closed negotiations with the Canada Great Northern to complete and work its road from a point near Comber Station to the village of Leamington on Pigeon Bay, Lake Erie, and work has commenced. The following applications will be made to the Canadian Parliament next session:—By the Gouris and Rocky Mountain Railway Company, for an amendment to the charter to enable the company to construct its line and branches north of the 51° of north latitude. For an act to incorporate the Gaskatchewan and Peace River Railway Company to construct and work a railway from a point on the north branch of the Gaskatchewan River, between Fort a la Corne and Carleton, running northwesterly to the Peace River. By the Ottawa, Vaudreuil, and Montreal Railway Company, for an act to further extend the time for construction of the portion of the line between West Hawkesbury and Ottawa. By the Grand Trunk Railway Company, for an act to authorize the Grand Trunk Railway Company, for an act to authorize the company to purchase, lease, or amalgamate with any line of railway whose line touches or intersects any part of its line.

At a conference of railway managers held last week at Brussels, for the organization of the Continental international service during the present year, the opening of the St. Gothard line throughout its entire length was provisionally fixed for July 1st, and arrangements were made accordingly. The opening of the great tunnel has already increased the traffic between the valleys of the Reuss and the Tessin more than fourfold. Although in former years the traffic at this season was little more than nominal, every train is now filled with passengers.

We learn from the *Annales Industrielles* that it appears that the French Government has definitely abandoned the Achard brake, and has decided to adopt the comparatively new automatic vacuum brake due to Mr. Wenger. Our contemporary thinks it very curious that the State should recommend the air-pressure brake and adopt the vacuum. Inasmuch as several thousands of engines and vehicles have been, and are being fitted, with the Westinghouse brake, it does seem curious, that is, if our contemporary has learned his story aright, which does not seem probable.

Traveling on the New Zealand railways is not, according to a writer in the *Colonies and India*, all pleasure. He says:—"The speed seldom exceeds fifteen miles an hour, and so many of the lines are over steep hills, and are laid out with such an evident fondness for curves, that a high or even average speed is out of the question. Experience in this colony is hardly in favor of Government lines of railroad. There is only too much truth in the common remark that the lines are laid off with far more consideration for the convenience and property of influential landowners than regard for the levels of the land or the convenience of the majority. The grinding of the wheels upon the rails as curve after curve is described by the train is continually suggestive, not only of danger and rapid wear and tear, but of the question why, with plenty of level land about, the train turns sharp corners and mounts steep hills. Only one answer is given, viz., that a Government railroad means a political railroad. Only two classes of passengers are carried—first and second — the former paying 3d. and the latter 2d. per mile. The New Zealand railroads are now beginning to pay interest upon their cost, as well as working expenses. Notwithstanding all the blundering and extravagance in their construction, I believe that it would pay an English company well to take over these railways at their cost, and work them upon commercial principles, though I fear there is little likelihood of a colonial Government giving up so convenient an instrument of influence and power."

ORDNANCE AND NAVAL.

Recent Advances in Gunmaking.—A lecture on this subject was delivered on January 13, before the Portsmouth Military Association, by Col. Maitland, Superintendent of the Royal Gun Factory, Woolwich. The lecture was illustrated by sections and diagrams of English, French, and German guns, breech mechanism, &c. Having described the metallurgy of gun construction and the action of various kinds of gunpowder, Col. Maitland said that we should be led to substitute steel for the weaker metal throughout the piece, as had been done by the Germans and the French. A very dangerous rival, however, had entered the lists against forged steel as a material for ordinance in the shape of tempered steel wire. Unfortunately, the wires had no cohesion with one another, and the great difficulty was to obtain what gunmakers called dead strength. It was of little use to make the walls strong enough if the first round blew the breech out. In the early days of wire this was what happened, and Mr. Longridge, who invented the system, was compelled to abandon it. Lately, methods had been devised for getting end strength. They were, however, in the experimental stage, and he could not say whether they would prove successful. Colonel Maitland then proceeded to describe the construction of heavy breech-loading guns. The Germans, he said, had a tube, a jacket, and hoops; the French a thick tube or body and hoops; and the English a tube, a jacket, and an overcoat, as it might be called. In the German guns the tube and hoops did nothing, as the jacket was considered sufficient. The French construction relied entirely upon the thick body, while the English method aimed at utilizing the whole section of the gun in both directions. Of course, if the other systems were strong enough, there was no particular advantage in this, and it was by no means improbable that we might eventually find it cheaper and equally good to substitute hoops for the overcoat. He next proceeded to touch upon a question which had been long hotly debated, and about which an immense quantity of matter had been spoken and written. The controversy between the breech-loading and the muzzle-loading principles had been a remarkable one, and, perhaps, the most remarkable part of it was the circumstance that, while there was now little doubt that the advocates of breech loading were right, their reasons were for the most part fallacious. It was commonly stated that a gun loaded at the breech could be more rapidly fired. This was certainly not the case, at any rate with the comparatively short guns which were made upon both systems a few years ago. It was also freely stated that with breech loaders greater protection was afforded to the gunners. This entirely depended on how the guns were mounted. If in siege works or *en barbette*, it was much easier to load a muzzle loader under cover than a breech loader. The real cause which had rendered breech loading an absolute necessity was the improvement which had been made in the powder. The slower the combustion of the powder the less difference there would be in the pressures exerted by the gas at the breech and at the muzzle, and the greater would be the advantage of lengthening the bore, and so keeping the shot under the influence of the pressure. Hence all recent improvements had tended towards larger charges of slower burning powder and increased length of bore; and it was evident that the longer the bore, the greater was the convenience of putting the charge in behind. Another advantage of the new system was the facility afforded for enlarging the powder chamber of the gun, so that a comparatively short, thick cartridge might be employed, without any definite restriction due to the size of bore. There was also another point in which breech loading had been found in the Royal Gun Factory to have a great advantage over muzzle loading as regards ballistic effect. With a shot loaded from the front it must be smaller all over than the bore, or it would not pass down to its seat. A shot thrust in behind, on the contrary, might be furnished with a band or sheath of comparatively soft metal larger than the bore. The gas then acting from the base of the projectile forced the band through the grooves, sealing the escape in a very satisfactory way, centering the projectile, and to a great extent mitigating the corroding effects of the gas. Artillerists were aware that the effect of the resistance offered by the band on the powder was to cause more complete combustion of the charge before the shot moved, and therefore to raise the velocity and the pressure. But it had escaped notice that this circumstance afforded a ready mode of regulating the consumption of the charge so as to obtain the best results. Having settled that the gun of the future was to be a breech loader, Colonel Maitland described various methods which had been adopted for closing the breech. It was, he remarked, difficult to compare the excellence of the different systems, as much depended on the care of the gunners and the niceties of manufacture. As regarded durability there was probably no great difference. As to the general principle of gun construction it should not be overloooked that the motive power was powder, and the purpose to be accomplished a hole in an armor plate, perhaps a breach in a concealed escarp, or destructive effect on troops. No single gun was capable of realizing more than one result in the highest state of excellency. For armor piercing a long pointed bolt was required. It must strike with very great velocity, and be propelled by a very large charge of powder. Hence, an armor-piercing gun should have a large chamber, and a comparatively small bore of great length. For breaching fortifications, on the other hand, it was clear that for a shell to drop at an angle of 15 deg. to 20 deg. at the end of a moderate range, the velocity at starting must be low. Hence, for pieces intended for breaching, no enlarged powder chamber was wanted. What was required was a large bore, but without any great length. For use against troops it was necessary in order to obtain the best results from shrapnel, that a considerable remaining velocity was needed. The gun must consequently have a large powder charge, while as the shell had to hold as many bullets as possible the bore should be large enough to take a shortish projectile of the given weight; the shrapnel gun would thus be intermediate between the armor-piercing and the shell gun.

In conclusion, Colonel Maitland remarked that there were certain axioms which were known from experience. The length of the powder chamber should not be more than three and a half times the diameter, because with longer charges the inflamed powder-gas was apt to acquire rapid motion and to set up violent local pressures. The strength of a heavy gun should not be less than about four times the strain expected. Though there were several opinions as to the best weight of shot for armor piercing in proportion to diameter, yet there was a growing tendency towards increased weight. He believed that the competition among scientific artillerists was now more keen than it had ever been, and if England was to keep her place in the van of progress she must afford every facility for experiment. She must neither spare expense in the Royal establishments nor discourage private enterprise, to which so much was owing.

COMMUNICATION WITH SHIPWRECLED VESSELS.—Some interesting gun experiments are being made for communicating with vessels in distress. The gun selected for the purpose is 2 feet long, with 2½-inch bore, and shoots a line 200 yds. with 2 oz. of gunpowder. The shot consists of a canister, which, on being discharged from the gun, leaves a line streaming behind it. The distance the line to be projected can be increased by increasing the size of the gun. Hitherto, the usual mode of communicating with shipwrecked vessels from the shore has been by means of rockets. Science, however, suggests that more effectual means may probably be arrived at by diligent research, and with this object the present gun experiments are being carried out.

STEEL-FACED ARMOR-PLATE TRIALS.—The first armor plate for the protection of the double screw barbette ship *Collingwood*, 9,150 tons displacement, now building at Pembroke, was tested on board the *Nettle*, at Portsmouth, on January 6. It is intended to protect the sides of the *Collingwood* by side armor of the great solid thickness of 18 inches, of which the steel face is 6 inches and the iron backing 12 inches. Each plate will measure 8 feet in height and about 12 feet in length, the lowermost plates of the series tapering from one-half of their length to 8 inches at the lower edge below the water line. The plate tested, as a sample plate of from 400 too 500 tons of similar plates, is intended for the citadel, which will be protected by plates of the same weight, but rolled from 18 inches to 11 inches in thickness, of which 3¾ are steel and 7¼ iron. It was manufactured by Messrs. Charles Cammell and Company, Sheffield, according to Wilson's patent, measured 8 feet in height by 6 feet in breadth, and weighed 9 tons 16 cwt. The remarkably satisfactory manner in which it passed through the crucial ordeal by fire, demonstrated the great perfection to which the manufacturers have attained. Three shots were fired at it at 30 feet range with the 12-ton 9-inch muzzle-loading rifle gun, the charge being 50 lbs., the weight of projectile 250 lbs. and the initial velocity 1,450 feet per second. The first round struck 2 feet 6 inches from the right edge and 4 feet 6 inches from the lower edge. The indent measured 10 inches by 9½ inches. The impact produced four very fine cracks, the first being circumferential to the indent, and none of them of any consequence. The projectile was knocked out of the plate by the blow of the second shot, when it was ascertained that the penetration had not proceeded beyond 4.5 inch. The next round struck the target 2 feet from the right and 2 6½ inches from the lower edge, and making an indent 10½ inches by 10 inches in diameter. The result of the blow was to produce three more hair cracks and to open out No. 3 crack slightly. On removing the wedge, however, from the frame, it was found to extend no further than just through the steel face. As the head of the projectile remained embedded in the plate, the depth of the penetration could not be measured. The third and final round struck 2 feet 1 inch from the left and 3 feet 6 inches from the lower edge. The diameter of the indent was 9 inches by 10½ inches, and the penetration 4.7 inch. No fresh cracks were made by this shot, but it caused Nos. 2 and 5, produced by the previous rounds, to extend to the edge of the plate. The whole of the projectiles were broken up into unusually small pieces. This plate is the most satisfactory that has yet been operated upon. The penetration was comparatively small, and, while the cracks were few and unimportant, none of them piercing the backing, there was no buckling of the plate observable, which is also quite exceptional.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

MONTHLY WEATHER REVIEW FOR JANUARY. Washington: Government Printing Office.

SCIENTIFIC PROCEEDINGS OF THE OHIO MECHANICS' INSTITUTE. Cincinnati: Published by the Institute.

LETTERS FROM LEADING ENGINEERS AND NAVAL ARCHITECTS AS TO THE PRACTICABILITY OF CONSTRUCTING AND OPERATING A SHIP RAILWAY. St. Louis; G. I. Jones & Co.

PROCEEDINGS OF THE ENGINEERS' CLUB OF PHILADELPHIA. Vol. 2, No. 3.

AERIAL NAVIGATION. By William Pole, F. R. S. Published by Institution of Civil Engineers.

ABSTRACT OF PROCEEDINGS OF THE SOCIETY OF ARTS FOR 18TH AND 19TH YEARS. Massachusetts Institute of Technology.

HISTORY OF THE WATER SUPPLY OF THE WORLD. By THOMAS J. BELL. Cincinatti: Peter G. Thompson.

DE INDISCHE GIDS. January, 1882. Amsterdam: J. H. DeBussy.

The British Navy; Its Strength, Resources and Administration. By Sir Thomas Brassey, K.C.B., M.P., M.A. Vol. 1. Part I., Shipbuilding for the purposes of war. London: Longmans, Green & Co. Price $5 00.

The present volume, although one of a series of six, appears in the market to be sold as a separate work, as it contains that portion which alone will be of popular interest. The second volume will treat of armor, armaments, torpedoes, etc. The third is a collection of papers giving the views of different authorities on the shipbuilding policy of Great Britain. The fourth and fifth volumes contain parliamentary speeches, and essays contributed to the Reviews. The sixth volume is a reprint of a former work on merchant seamen.

The contents of the first volume are—Historical Sketch, Naval Requirements in War, Classification of Ships of War, Earliest Ironclads, Progress of Armored Ship building in France, from 1861 to 1873, Early Armored Construction in England, Converted Ships, Sir E. J. Reed's system; Austrian, German, Italian, Turkish, Russian and Spanish Iron-clads; Monitors and Earlier Armored Vessels for Coast Service. Vessels of More Recent Type: Armored Cruisers, Bow Battery-Ships, Central Battery-Ships, Masted Turret-Ships, Mastless Turret-Ships, Mastless Barbette Ships, Unarmored Cruisers and Special Vessels of the Chief Naval Powers.

The details of construction of the principal war vessels are exhibited in a series of folding plates, fourteen in number, in which coloring is used to aid in distinguishing parts exhibited in sections. Full page wood cuts of twenty-five of the celebrated ships and lesser cuts to the number of 310 illustrate the text.

Much patient, skillful labor has been expended in the preparation of this handsome volume. The author's own view of the character and importance of the work is fairly expressed in the following paragraph from the preface:

"Days and nights which should have been given to rest from other labors, to literary culture, and the kindly offices of friendship have been devoted to the present work, and no small portion of it has been prepared under conditions far from favorable, in a scanty cabin, six feet square, rocked on the uneasy billows of the open ocean. I could not have persevered if I had not felt it my duty to bring to completion the enterprise on which I had embarked. The sea has been a passion with me from my boyhood; but it has only been in later life and by a chain of circumstances apparently fortuitous, that the disappointed memories of long vacations spent afloat, which should have been occupied with methodical study, have been partially soothed by the hope, in which I try to indulge, that my nautical experiences have been applied, not altogether in vain, to the service of my country."

Leçons sur l'Electricite et le Magnetisme.—Par E. Mascart et J. Joubert. Vol. I. Paris: G. Masson.

This is a theoretical treatise and is intended to explain to the French student the views of Faraday and Clark-Maxwell.

Seven hundred and twenty royal octavo pages, including 127 figures, are devoted to general phenomena and theories. Vol. II. is not yet published.

The Horse in Motion, as Shown by Instantaneous Photography.—By J. D. B. Stillman, A.M., M.D. Boston: James R. Osgood & Co. Price $10.00.

A large and elegant book is devoted to what might seem to be an unimportant subject; but a brief glance at the beautiful illustrations convinces at once that the subject justifies the space assigned to it, and the handsome form in which it is presented.

No better starting point for the treatise on animal mechanics could be conceived than the instantaneous views which illustrate so abundantly this volume.

Geological Survey of New Jersey.—Annual Report of the State Geologist for the year 1881. Trenton: John L. Murphy.

The Report is accompanied by a beautiful colored geological map of the State. The text covers something more than one hundred octavo pages, and treats of the following subjects:

The United States Coast and Geodetic Survey of New Jersey, Topographical Surveys, Geological Notes, Ores of Iron and other Metals, Quarry Stones and Statistics, Clays, Bricks, and Pottery, Drainage, Water Supply, Statistics, Publications, Expenses, Persons Employed, Work to be Done, Plan for the Coming year, Appendix, Climate, and Meteorology.

The State Geologist is Prof. George H. Cook; Assistant Geologist, Prof. John C. Smock.

A Manual of Sugar Analysis, Including the Applications in General of Analytical Methods to the Sugar Industry. With an Introduction on the Chemistry of Cane Sugar, Dextrose, Levulose, and Milk Sugar. By J. H. Tucker, Ph.D. New York: Van Nostrand. Price, $3.50.

It is a remarkable fact that extensive as are the interests connected with sugar, and frequent, or rather constant, as are the applications of chemical science which they require, there existed hitherto no work in the English language dealing systematically with this branch of chemical analysis. Our apathy on the subject is the more remarkable when it is considered that we are far greater sugar consumers than any other European country, and that the British Empire alone is probably able to supply more sugar than any other State in the world. France, Germany and Austria, on the other hand, have been as active as we have been remiss; and thanks to their energy and perseverance, beet-root sugar, one of the weapons devised against us by the first Napoleon, has become a formidable rival to the true cane sugar. We say "true," because, although analysis has hitherto not succeeded in showing any distinction between the saccharose of the cane and that of the beet, many persons can distinguish the two by the taste. Bees, we undestand, where they have the choice, will crowd to cane sugar and leave beet sugar untouched, and a suspicion is gradually gaining ground that the physiological action of these two sugars is not identical.

The author sets out with a summary of the chemistry of the sugars as a class, and then gives a more especial description of saccharose, to which he devotes an entire chapter on dextrose, levulose, and invert sugar and of lactose. We venture here to propound a question: Starch, it is said, in any of its forms, when taken as food, cannot be digested until converted into sugar. Why, then, are the physiological actions of starch and of sugar so different?

Dr. Tucker proceeds in the next chapter to the determination of the specific gravity of the solutions of sugars. It is somewhat remarkable that he omits all mention of Twaddle's hydrometer whilst speaking at length of the very inferior instrument of Baume, which has been so justly denounced by Professor Bolley. In the chapter on the determination of cane sugar by optical methods, he describes the saccharimeters of Mitscherlich, Soleil-Duboscq, and Soleil-Ventzke, Wild's polaristrobometer, the "shadow saccharimeters" of Duboscq and Schmidt and Hanesch, and the method of Clerget, with the accompanying table. He states in a note that this process (Clerget's) is entirely inapplicable when any optically active body is present besides cane sugar or invert sugar, and also if the invert sugar itself exists in an inactive condition as regards polarized light. To this criticism we cannot subscribe.

The chemical methods for the determination of cane sugar next follow. The process of Peligot is not regarded as very accurate; extraction by alcohol gives good results where the quantities to be dealt with are but small. The fermentation process is justly pronounced "open to many objections." The processes for the analysis of raw sugars and sirups are the best known, and they are ably and clearly described. Still, we fear that they will, under very possible circumstances prove unsatisfactory in practice. Further research is needed before the analyst can find himself in possession of methods suitable for every possible mixture of a class of bodies so nearly related in composition and not marked by any very striking reactions. An important section is devoted to the detection of two modern and increasing frauds—the addition of dextrin, and of starch, or corn sugar, to raw or refined sugars. Dextrin is added to raw sugars to give them a higher polarization: 0.40 per cent of dextrin raises the optical standard 1 per cent. For its qualitative detection the author adds in a concentrated solution of the sample alcohol at 95 per cent. A white, thread-like coagulum shows the presence of the adulteration. Unfortunately, calcium sulphate gives a similar result. Iodised potassium iodide gives a vinous red, or violet color, with some samples of dextrine, but not with all.

Starch or corn sugar is now, at least in America, added in large proportions to sugar, sirups, preserved fruits, &c., and goes under the euphemistic name of "new process sugar." Its price is unfortunately very low—about 3d. per lb.—so as to leave a large margin for the unscrupulous. We may here remark that, according to the experiments of Professor Nessler, this substance is decidedly unwholesome. The author admits that there is no accurate method for the quantitative determination of this adulterant. Its presence may be qualitatively detected by attending to the three following points: Sugars mixed with corn glucose on solution in water leave white particles of the glucose undissolved. If a sugar adulterated in this manner is examined with the polariscope, the reading does not remain constant, but gradually becomes less. A refined sugar mixed with starch sugar will show too high a percentage by the saccharimeter, so that the results appear more than 100 per cent. Two chapters are devoted to animal charcoal. Amongst the synonyms of this substance the author omits the name "spodium," which it commonly bears in Germany. The following passage deserves especial notice:—"There has been a method proposed in France for the estimation of cane sugar in raw sugars, known as the *four-fifths method*, and is, I believe, used to some extent in commercial analysis. It consists in taking four-fifths of the ash as the number expressing organic matter, not sugar. The sum of this—the ash, water and glucose—subtracted from 100 represents the cane sugar. The method is not worth mentioning, except as a curious example of the aberations to which the human mind is subject." This process outdoes even the so-called "commercial method" of determining phosphoric acid in coprolites, superphosphates, &c., viz , by adding ammonia and accounting for the entire precipitate as tricalcic phosphate.

Dr. Tucker's work is well illustrated, and in case of some of the less common instruments described and figured, the adress of the maker is given in a foot note. The getting-up of the book is excellent, with, perhaps, the exception of the index and of certain tables, which are in an uncomfortably small type. The work decidedly supplies a want which must long have been felt, and it places in the hands of the profession information which must otherwise be sought up, at great outlay of time, in the foreign journals.—*Chemical News.*

MISCELLANEOUS.

DYNAMO-ELECTRIC machines are now being used in porcelain manufacture. The paste used for porcelain often contains ferruginous particles, which give the baked articles a color, or a minutely spotted appearance, where a pure white may have been desired. In this way ceramic products may lose as much as 50 per cent. of their value. The attempt hitherto made to remove those traces of iron with magnets have met with poor success. Recently, however, at two important French works, the Faïencere of Creil, and the establishment of MM. Pilivuyt & Co., of Mehun-sur Yevre, it was decided to set up powerful apparatus in which the electricity, instead of being supplied from batteries, was obtained by means of a small Gramme machine driven by a steam engine. The arrangement, which is said to work well, comprises a strong horizontal electro-magnet, with the poles very near each other, and between them a thin box. The paste, very liquid, enters the upper part of this box and is deflected towards the polar sides by a bent piece of zinc. As it flows down these sides the iron corpuscles are caught on them by the magnetic force. The apparatus is cleaned twice a day, by means of a jet of water, the magnet being demagnetized for the time. About 1 gramme of iron particles is stopped in the passage of 12 kilos. of paste, and 500 to 600 kilos. of paste may be passed through one apparatus in a day.

THERE is considerable disparity in engineers' opinions respecting crowd weights, or the actual weight which should be allowed for as the crowd load of a bridge. The following is from *Calvert's Mechanics' Almanac*: Mr. E. A. Cowper states that he had placed a number of men together, and they weighed 140 lbs. to the square foot. Mr. Parsey is of opinion that, upon an average, men, when put together closely, would weigh at least 112 lbs. per square foot, but in ordinary crowds of people 80 lbs. might be taken as sufficient. While Englishmen would weigh about 150 lbs., a Belgian would weigh 140 lbs., and a Frenchman 136 lbs. Mr. F. Young, at a meeting of the Society of Engineers, said 80 lbs. per square foot was quite safe in practice. Mr. George Gordon Page, in a paper on the construction of Chelsea Suspension Bridge, says for troops on march, 21in. in rank and 30in. in pace are allowed, giving 4.37 superficial feet per man, which, at 11 stone, would be 35½ lbs per square foot. The load taken in the calculation for the Menai Bridge was 43 lbs. per superficial foot. An experiment was made by the engineer of the Chelsea Bridge, by packing picked men on a weighbridge, with a result of 84 lbs. per superficial foot, but it is not likely that such a crowd could accumulate on any bridge. It may here, perhaps, be useful to add that a cavalry horse weighs about 11 cwt.; a strong cart horse, about 14 cwt.; and a riding horse, about 8 cwt. The weight of horses in the United States ranges from 800 lbs. to 1200 lbs. The average weight of 2000 men and women, weighed at Boston, 1864, was—men, 141½ lbs.; women, 124½ lbs. The average weight of an elephant is 60 cwt.; a camel, 10½ cwt; large ox, 10 cwt.; small ox, 6 cwt.; cow, 6½ cwt.; heifer, 3½ cwt.; pig, 1½ cwt.; and sheep, 60 lbs. to 90 lbs.

THE committee announce that the new inventions not patented, exhibited at the Smoke Abatement Exhibition, are protected by special provisions of the Board of Trade. They also state that inventors having apparatus of which models cannot be prepared in time for exhibition may send in drawings of the same.

ACTION OF LIGHT ON SILVER RESISTANCES. —The researches of Professer Bell, M. Mercadier, and others have shown that selenium is not the only substance which is affected in its electric resistance by light; and the recent experiments of M. Bœrnstein would appear to demonstrate that silver should also be added to the category. He took two plates of glass chemically covered with a thin coat of silver. The ends of the plates were electrotyped with copper and used to connect the two other branches of a Wheatstone "bridge." When a balance had been obtained one of the films of silver was lit by the ray from a spirit lamp colored with sodium. The influence of the light was to increase the resistance of the silver, and that the maximum resistance was only attained at the end of a certain time. It would be more satisfactory to feel sure that the increase of resistance was not due to heating by the rays.

A NEW MAGNETO-ELECTRIC EXPLODER.—M. Marcel Deprez, the eminent French electrician, has constructed a new magneto-electric machine for exploding mines and torpedoes which possesses several points of interest. Instead of passing the instantaneous current induced in the coiled armature suddenly snatched from the poles of the magnet, directly through the wires to the fuse in the mine, he passes it through the primary circuit of an induction coil, and the secondary spark from this coil is sent along the wires to explode the mine. This change necessitates some modification in the exploder as ordinarily made. For instance, the wire of the armature coil ought to be thick so as to give small resistance, and the induced current due to the withdrawal of the armature should be broken when at its maximum strength, in order that the rupture may induce a maximum current in the secondary circuit of the induction coil. M. Deprez also found that ordinarily the armatures of exploders contained too much iron, and he has therefore reduced this feature. In the new exploder of M. Deprez, the armature consists of a coil of stout wire wound on a core of sheet iron which is carried by two crank levers mounted on the same axle. By striking a small pedal attached to the other arms of these levers the armature is suddenly jerked away from the poles of the horseshoe permanent magnet it rests against, and the spark generated flows into the primary of the induction coil. The interrupter of the latter is to be adjusted so as to give the longest spark from the secondary.

ON CEMENT.—Some useful results obtained by German experimenters on the behavior of cement under different conditions are given in the current volume of *Dingler's Polytechniches Journal*, p. 1088. According to Herr Schumann, all cements, if allowed to harden in water, increase in volume, the largest increase taking place during the first period of settling. The increase is larger with newly-prepared cement, smaller with finely-ground cement. The addition of gypsum also increases it, while the admixture of sand diminishes it. Building stones were likewise found by Schumann to expand in water, and contract again on being dried in air. The greater the porosity of the stone the smaller is the increase in volume. These changes are, however, in his opinion, too slight to interfere with present practice in building operations. With regard to the behavior of concrete under heat, Herr Feege finds that it can be exposed to a temperature of 130 deg. to 150 deg. Cent. without injuring its supporting strength. At higher temperatures, however, it loses firmness and becomes brittle. An important fact bearing on the preparation of mortar was elicited by Schumann's experiments. He found that that all cements, whether used as fine or coarse powder, or burnt slightly or strongly, give the same yield of mortar, and therefore recommends weighing the quantity of cement instead of measuring it as is usually the case. We should add that Herr Delbruck objects to prepare concrete under water, and holds that all excavations should be kept as dry as possible during the actual process of concreting. Herren Busing and Dyckeshoff, on the other hand, strongly recommend concreting in water, and cite many large undertakings in which it has been successfully effected.

SHIPBUILDING.—The tonnage statements of the vessels that have been launched last year show the marked progress that has been made in shipbuilding at many of the chief ports, and the great competition that has been known amongst some of the chief shipbuilders. The first place is taken by the Palmer Shipbuilding Company, of Jarrow, which has launched over 50,000 tons of shipping. But the second position on this occasion seems to have passed to Barrow-in-Furness by a few tons; the third place in the rank of producing firms being taken by Messrs. W. Gray & Co., of West Hartlepool. The largeness of the contributions to the total are remarkable, and the extent to which the northeastern district—from Blyth to Whitby—has launched vessels, is also very notable. But it will be probably found when the figures for that district are analyzed, that there has been in the past year a reduction in the tonnage of steel steamers built, as compared with the previous year. The demand for iron vessels has been so large that firms that had previously entered into the building of steel vessels have laid it aside. Another fact that strikes the inquirer is, that the vessels built are now such as consume a larger quantity of iron than formerly—many parts of the vessels that were built of wood down to a short time ago, have now been generally made of iron. There is a distinct tendency, moreover, to increase the average tonnage of the vessels built. But on all points the year 1882 opens with prospects for the shipbuilders that are brighter than were those of its predecessor. There is on all hands fullness of work, and in some instances orders that will last through the whole of the year, so that, failing any unexpected check the tonnage built in 1882 should be above that of the past year.

THE CALORIC OF CARBON.—Mr. Jacob Reese, in a paper read before the Engineers' Society of Western Pennsylvania, remarks:—"The great want of the present age is a process by which the static caloric of carbon may be set free by non-luminous combustion, or, in other words, a process by which coal or oil may be oxidized at a low degree within an insulated vessel." This cannot be too prominently brought forward. "If it can be accomplished," as Mr. Reese says, "we would be able to produce from twelve to fifteen million foot-pounds of electricity from one pound of petroleum, or from ten to twelve million foot-pounds of energy from one pound of good coal."

THE NEW ATLANTIC CABLE.—The steamship *Faraday* left the works of Messrs. Siemens Brothers at Charlton on January 10, with the last portion of the New Atlantic telegraph table, which is to be forthwith completed for the American firm of Gould & Co. The cable is of special kind and remarkable for its strength, the shore end weighing 18 tons per mile and the deep sea and intermediate sections being to correspond. More than 1,100 miles have been taken on board at the rate of 50 miles per day, and the cable, when completed, will be 3,000 miles in length. The *Faraday* has made three voyages on the same work, leaving the end of the cable on each occasion buoyed in the Atlantic, where it has endured the storms of the past year without the slightest injury.

EXTENSIVE USE OF ELECTRIC LIGHT ON THE CONTINENT.—A scheme is on foot, says *Nature*, having been approved by the Municipal Council of Paris, for lighting with electricity the quarters of the Prefecture of the Seine, in the Tuileries. It is the work of M. Cernesson, and comprises lighting the Salle des Séances with eighty Swan lamps (in place of eighty Carcel lamps), and six Siemens' arc lamps; lighting the library with forty-eight Maxim incandescent lamps (on the present lusters); another room with twenty-four Lane-Fox incandescent lamps; another with twenty Swan lamps; the Salle des Pas Perdus with two Werdermann lamps; a lobby with two Siemens, lamps, and a staircaise with four Brush lamps. The whole will require an outlay of 75,000 fr. The horse power necessary is 44, and while the idea of obtaining this from the Seine has been considered, it has been decided to set up a gas engine in the Court of the Tuileries. A portion of the motor force is to be employed for electric hoists, for driving ventilators, and other uses. The Paris-Lyon-Méditerranée Company have illuminated their Paris terminus with fifty-four electric lamps on Lontin's system, and that of Marseilles with seventeen of the same lamps, a number which is to be increased by eighteen. The French Northern Company has tried, with success, the use of the electric light in the front of locomotives. The Turin Municipality have decided on trying the electric light for the Theater Royal.

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ON TORPEDO BOATS AND LIGHT YACHTS FOR HIGH SPEED STEAM NAVIGATION.

By JOHN ISAAC THORNYCROFT, M. Inst. C.E.

From Proceedings of the Institution of Civil Engineers.

I.

The services for which torpedo boats and steam yachts are required render it imperative that they should be capable of attaining high speeds, that they should work silently, and that they should be of limited dimensions. They must also possess great propelling power in proportion to their total weight or displacement; that is to say, whilst the propelling power must be ample, the displacement must be reduced to a minimum. It will be expedient to examine how the two conditions of lightness and sufficient power may best be obtained, and what practical means have hitherto been adopted for giving effect to them. For this purpose the total weight or displacement of a vessel may be conveniently divided into three components: 1st. The structural hull, as defined by the late Mr. Froude; 2nd. The propelling machinery and apparatus; 3d. The load.

The third of these, the load, is comparatively insignificant. In torpedo boats the load consists of torpedoes and the fighting gear; in steam yachts, the cabin fittings. The first component, the hull, depends practically on the second, and it cannot safely be made less in weight than a certain fraction, well defined, of the sum of the two other components. Most progress is to be hoped, therefore, from the treatment of the second component, and in reducing the weight of the propelling machinery and apparatus, the weight of the hull, too, may be reduced.

The general conditions on which the reduction of the weight and the volume of the propelling machinery and apparatus is dependent, may be briefly summarised as follows:—Rapid combustion of fuel, subdivided flue way, in order to multiply the heating surface; high steam pressure, and high speed of engine—speed of revolution as well as of piston, particularly the former as the more important of the two. Such are the characteristic features of the locomotive engine, in which they were first developed, and it may be useful to sketch the progress of the locomotive as the embodiment of extreme lightness and concentration of power.

The earliest locomotives, used for working coal trains on tramways, were little more than reflections of the ordinary practice of the stationary engines of the time, in which the element of weight was not in itself objectionable. The fires were urged simply by the natural draught of the chimney, assisted occasionally by the exhaust steam turned into the chimney; and the heating surface consisted of the iron-plate furnace and the iron flue. Under these circumstances, from 30 lbs. to 40 lbs. of coal were consumed per square foot of fire-grate per hour, whilst the quantity of water evaporated per lb. of coal did not amount to more than from 3½ lbs. to 4 lbs., and the pressure of steam in the boiler did not probably exceed 15 lbs. or 20 lbs. per square inch. Suffice it to state, in addition, that in the course of improvement the current of hot gases was subdivided, by the multitubular flue, into numerous streams enclosed within extensively developed surfaces, as initiated in the historic "Rocket" locomotive. But the draught, and consequently the rate of combustion of the fuel, were vastly accelerated by the introduction of the blast pipe for directing the exhaust steam up the chimney, insomuch that from 50 lbs. to 100 lbs., and even still higher rates of combustion of fuel per square foot of fire grate are now practiced; that higher pressures have adopted, augmented progressively from 50 lbs, to 140 lbs. per square inch; and that the cylinders have universally been connected directly to the driving or crank axle, making from two hundred to two hundred and fifty revolutions per minute, with speeds of piston of from 600 to 1,000 feet per minute.

With such a practical example of combined lightness and power, it followed naturally that much of what had been matured in the practice of the locomotive on railways was adopted for the propulsion of high-speed vessels of limited dimensions on water. But there are at the same time important differences in the circumstances of the two cases under which the engines work. In water, the engines are required to put forth their full power continuously for long periods, for there is nothing corresponding to a level road or a bank sloping downwards, after an ascent on an incline, to relieve the stress. Full power is unremittingly required to keep up full speed, whilst the water ever assumes the form of an inclined plane upward. Boiler power is, under such circumstances, continually tasked to its utmost capacity, and a larger boiler is required for cylinders of given dimensions than is necessary under the circumstances of railway traction. Moreover, for surface-condensing engines, from which the soft water of condensation is returned to the boiler, a greater proportion of steam room is necessary. The bearing surfaces of the engines, likewise, are required to be larger, in order to keep the working parts cool.

In the swift American river boats high-pressure steam is used, either with or without condensation, whilst the fires are forced by means of a fan blast or a blow pipe in the chimney. But the high speeds of which they are capable have, for the most part, been effected with great dimensions; for, with large paddle wheels and long strokes, their engines are necessarily heavy and bulky, and although a considerable speed of piston is attained in virtue of the long stroke, a high speed of revolution is impracticable.

The large space occupied by paddle engines, and the great weight involved in their construction, were partially reduced by the introduction of oscillating cylinders, though here a difficulty was encountered in employing steam of high pressure; and with relatively low pressure and low speed of pistons, cylinders of large capacity were unavoidable. Many swift paddle steamers have been built with oscillating cylinders, and they are beautiful structures of their kind; but the cylinders are so large as to occupy nearly all the mid-ship sectional area of the vessel. To make way for higher pressures with paddle engines, many constructors have returned to fixed cylinders, with connecting rods; but when such engines are, for the sake of length, placed in an inclined position within a vessel, they are open to the objection of occupying considerable room, besides the fundamental objection of heaviness in comparison to the work that can be done with them.

When the screw came to the front as a rival to the paddle, a new opening was made for augmenting the speed of marine engines, although at first the opportunity was not embraced, seeing that intermediate gearing was employed to bring up the speed of revolution of the screw, whilst the speed of the engine remained relatively low. But the reducing gear was ultimately suppressed, and the screw was driven direct by the engines, which were connected to the screw shaft; and compact engines of quick revolution, with high speed of pistons, worked under high pressures, were brought into successful operation.

Under the stress of competition, the demand for economy of the space occupied by the boiler and the coals was keenly felt, most of all for long voyages, for which the first ocean vessels working at high pressure were built. Besides, the higher the pressure, the smaller may be the boiler, at least so far as the steam room may be proportioned; and there does not appear to be in use at present better boilers than those of the locomotive type, which are light and trustworthy, for the service of torpedo boats and steam yachts. It is to be noted, nevertheless, that a limit is imposed on the degree of pressure that may be available, by the limit of temperature of the steam, which increases with the pressure at which an engine can be worked.

The Herreshoff boiler claims some notice, as it is light, and is of small capacity, containing designedly but a limited quantity of water, in itself conducive to safety. This boiler consists of little else than a coil, by which the water supply is connected with the steam pipe and separator. The feed water, introduced at the top, falls by gravitation, and its fall is accelerated by the stream of steam disengaged in the course of its passage downwards, by the only way out in fact. The boiler appears, at first sight, to promise good results. But so even a balance is required between the fire and the feed water that the boiler is not likely to be maintained, even for a short time, in the most favorable conditions for work; and should the supply of water fall short of the normal quantity, the steam would be highly superheated, and the engines would be seriously damaged. By an excess of water supply, on the contrary, the heat of the fire would be taken up, without the performance of useful work, and with a corresponding loss of economy. But the question remains, What are the merits of the Herreshoff boiler, under the best conditions that can be maintained, with a small excess of feed water?

For the purpose of forcing the draught of marine boilers, the fan appears to be the most convenient instrument. Fans have occasionally been set to work in the flues, operating by suction on the products of combustion after they have left the boiler; but they could not last long there, exposed to high temperatures. The author prefers to stimulate the draught by forcing air into the stokehole. By this means, a better action is maintained, whilst at the same time the stokehole is kept moderately cool. He devised the fan blast in this form for the boilers of the yacht "Gitana," built by him in 1876, and it has been found to work efficiently. The pressure of the blast used for the boilers of the "Gitana" and other boats of its class is measured by a column of water, from 3 inches to 6 inches high. The greater part of the pressure is exerted in overcoming the resistance of the flue tubes of the boiler. The degree of blast pressure that may safely be employed depends very much on the length and the diameter of the tubes, as well as upon the width of the water interspaces between them. If large, flue tubes were used in a boiler, the author is of opinion that the limits of safety might easily be exceeded; and although the maintenance of a plenum in the stokehole is satisfactory in operation, he feels that it must be employed with caution, particularly in its application to boilers having small fire grates and large sectional area of flue ways. The risk of damage would, of course, be greatly increased by internal deposits.

In using steam of high pressure, the compound engine is generally adopted, for stationary as well as for marine propulsion; though in locomotive practice the cylinders, as yet, have but rarely been compounded. There are three advantages attendant on the employment of compound engines compared with single-cylinder engines—a more nearly uniform distribution of pressure during the stroke of the piston, accompanied by a better distribution of tangential pressure on the crank pins; a diminished range of temperature in each cylinder, and comparative simplicity of valve gear. A relatively high speed of engine may be taken as favorable for economy of steam, in consequence of the smaller area of cooling surface in the cylinders of high-speed engines than in those of low-speed engines, exerting equal power; as well as of the smaller circumferential passages for accidental leakage of steam about the pistons and the valves.

The proportion of expansion to which steam should be worked in compound engines, for the purpose of attaining the greatest economy of steam and fuel, was made the subject of many carefully-conducted experiments on the compound engines of the U. S. revenue steamer "Rush," in which the cylinders were thoroughly steam-jacketed with steam of 82 lbs. per square inch initial pressure. The most economical ratio of total expansion was found to be 6.22; and on board the "Dexter," where the engines had single cylinders without any steam jackets, the best ratio of expansion was 3½.

Having considered, in general terms, the conditions necessary for light propelling machinery, the author will now examine the relative weight and form of hull best adapted for carrying the load and the machinery. The weight of the hull depends principally, as already stated, upon the gross amount of weight to be carried. It is not much affected, within moderate limits of variation, by the proportions of the hull; but when the proportion of the length to the depth is increased, the weight of material necessary to secure sufficient longitudinal strength is inevitably also increased.

The shape of hull that should be adopted is the result of the most suitable compromise between several requirements, each of which, taken separately, dictates unfortunately a special form differing from the other forms. Speed is, for torpedo boats, a requirement of the first importance. The next is handiness, and this demands that the length should be shortened as much as is practicable. The element of frictional skin-resistance of the submerged surface of the hull should be reduced as much as possible. For this object, by cambering the keel, the area of the immersed surface and that of the dead wood is much lessened. The handiness of the vessel for turning is, at the same time, increased by diminishing the depth at the ends.

To augment the stability, the width of the deck may be increased considerably beyond the width measured at the water line. The increase of bulk thus effected augments the righting force, when any considerable inclination of the vessel from the vertical is reached, without impairing the speed. The freeboard, also, must be such that the angle at which stability vanishes is very large, so that there may not be any danger of capsizing. The suddenness with which waves are encountered when the vessel is in rapid motion requires that the form of the bows of the boat above water be not too bluff, otherwise the shocks which are sustained may endanger the structure. Nevertheless, considerable bulk must be maintained in the bows, in order to lift the forward part of the vessel. This lifting is greatly facilitated by making the ends light, and concentrating the load, as far as may be, about the center of the vessel

The most favorable position for the propeller for high speeds, is astern of the rudder; but, as little loss of speed is entailed by reversing the relative positions of the rudder and the screw, and as the steering qualities are improved by so doing, it is frequently preferred to place the screw in advance of the rudder, although the effect of the transposition is somewhat to increase the length and the weight of the boat at the stern. The question of immersion of the propeller is also important; but it is not easy of estimation in vessels of high speed relative to their size, as the change of trim involved by high speed frequently provides sufficient immersion, although when the vessel is at rest, immersion may not be complete. If the propeller breaks the surface of the water while in action, the air drawn down, in consequence, causes a greater loss than might be expected. Experiments were lately made by the author on a mode propeller, the performance of which was carefully noted, both when it was totally immersed and when it was working under such a state of immersion that it just broke the surface. In the first case, the useful effect was equal to about seven-tenths of the power expended, and the action was perfectly steady and easily recorded. In the second case, however, the condition of working varied so much that it was only with difficulty that the efficiency could be ascertained, and no precise value for the efficiency could be given, except in so far that a considerable loss was proved, for it did not appear that the efficiency exceeded five-tenths of the power expended.

For small vessels, it does not seem worth while to discuss the question of using one propeller or two propellers, as twin engines would involve so many duplicate pieces, that they could only be employed where the advantages to be derived from their use would be very great. For large vessels, they seem to be most desirable.

The relative position of vessels in motion, in the system of waves caused by and surrounding them, is of great interest, as it throws light on the cause of the low rate at which the resistance of hulls increases at relatively high speeds. It was ascertained by Mr. Bramwell in experimenting with the "Miranda" that a wave crest, situated near the stem at ordinary speeds, moved gradually towards the center of the vessel as the speed was increased to the maximum attained by the vessel. Mr. R. E. Froude has found that this wave crest is the foremost in the system, and that the advance of a vessel upon this crest has the effect of diminishing the wave slope which is opposed to the vessel's motion.

The author will now describe three boats built by his firm:—1, The yacht "Gitana," for the Baroness Adolphe Rothschild, for excursions on Lake Leman; 2, A first-class torpedo-boat, for the English Government, very similar to the "Lightning," the earliest boat of the class; 3, A second-class torpedo-boat, smaller than the preceding, many of which have been constructed for the English Government.

THE YACHT "GITANA."—Fig 1.

The length of the hull at the water-line is 86 feet, and the extreme length is 90 feet; the breadth of beam at the water-line is 10 feet 6 inches, and the extreme beam is 13 feet 2 inches. The draught of water is 4 feet aft, and 1 foot 1½ inch forward. The displacement is about 29 tons.

The engines are compound, condensing by injection, with an intermediate receiver. There are three cylinders, comprising a 13½-inch high-pressure cylin-

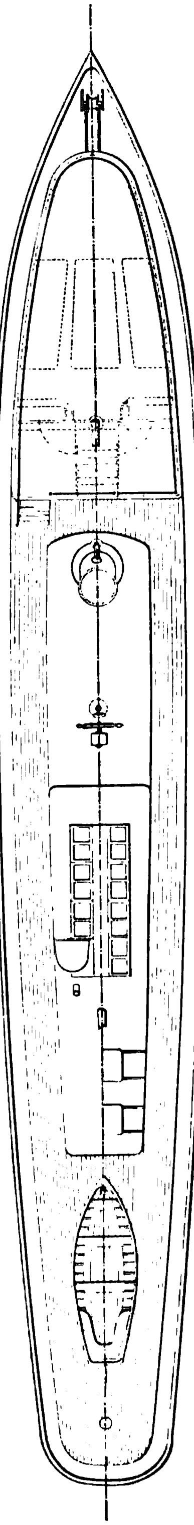


Fig. 1.

THE YACHT "GITANA"

der, and two 15-inch low-pressure cylinders, with a stroke of 16 inches, working on three cranks placed at equal angles. The air-pump is 23 inches in diameter, with a stroke of 3 inches, and is worked by levers from the high-pressure cylinder. The feed pump is double-acting, 2¾ inches in diameter, and is worked directly by a steam cylinder, with a stroke of 7 inches. There is, in addition, a Giffard injector of 5 millimeters. The fan for blowing the fire is 3½ feet in diameter, and is driven directly from a 5-inch steam cylinder, with a stroke of 3 inches, making about nine hundred revolutions per minute.

The propeller (Thornycroft's patent) is a screw of three blades, 5¼ feet in diameter, with a pitch of 8¼ feet; it is placed abaft the rudder.

The boiler is of the locomotive type, having a working pressure of 120 lbs. per square inch. The fire grate has an area of 16.2 square feet. There are one hundred and niety-seven flue-tubes, each 1¾ in diameter externally, and 8 feet 0½ inch long. The heating surface of the fire box is 52 square feet, and of the tubes 653 square feet, together 705 square feet of heating surface.

The slide-valves are so arranged as to cut off steam earlier in the stroke of the low-pressure cylinders than in that of the high-pressure cylinder, in order to equalize, as nearly as possible, the work between the three cylinders.

The framing of the main engine consists of small steel columns, directly connecting the cylinders with the bedplate, and placed as near to the main bearings as practicable. These columns are braced together near the center of their length, and are only adapted to resist vertical forces. The framing depends for transverse stability on its connection with the hull, to which the cylinders, and the lower ends of the guide bars, are fastened by stays.

For securing lightness of moving parts, the pistons are of wrought steel; the piston rods and connecting rods are also of steel, the piston rods being bored out. The cranks, the crank pins, and the lower halves of the connecting rods, are balanced by cast-iron balance weights, secured to the cranks by steel bolts.

The proportions of the blowing engine are unusual, a great length of bearings having been given. The combined length of the main bearings is 18 inches, their diameter being 2 inches; whilst the diameter of the steam cylinder is only 5 inches. The crank-pin is 4 inches long by two inches in diameter. The disk of the fan revolves within the engine room, without any external casing. It takes air in at one side only, from a large tube leading from the deck, and delivers it all round the circumference of the disc, without inconvenience. The shaft of this engine is fitted with thrust-collars to resist the unbalanced pressure of the air on the disc. Engines of this pattern have been worked at a speed of seventeen hundred revolutions per minute, or fifty-six strokes per second, without damage.

In estimating the effects of rapid change in the direction of stress on the journals of engines working at high speed, the author is of opinion that sufficient importance has not, in general, been attached to the fact that the lubricant has to sustain the pressure for but a very short time in one direction. This he considers is the principal reason why high-speed engines have so much less wear and tear than many persons appear to expect. It is, nevertheless, most important that correct adjustment should be maintained in order to secure good working results.

FIRST-CLASS TORPEDO-BOAT—Fig. 2.

This boat is 87 feet in length, with a breadth of beam of 10½ feet. The draught is 1 foot 6 inches forward, and 5 feet 2 inches aft, with a displacement of 32.4 tons. The engines are compound, with an intermediate receiver, having a 12¾-inch high-pressure cylinder, and a low pressure cylinder 20¾ inches in diameter, with a stroke of 12 inches. The cranks are at right angles. The air pump is worked by levers from the high-pressure cylinder, as is the engines of the "Gitana," making, of course, the same number of strokes per minute as as the engines. The condensing water is forced through the condenser by a centrifugal pump, with an auxiliary engine, assisted by a special form of grating, which, by means of gradually expanding openings, converts the external relative velocity of the water into pressure. The thrust-block is secured to the bedplate of the engine by two stays, one attached to each side, and level with the center of the shaft; thus preventing any tendency to throw undue thrust on the lower half. The slide-valves of the engines are balanced by being placed under bridges, which are made with recesses corresponding to the ports in the cylinders, as used by Mr. Wilson, of Patricroft. In order to obviate the difficulty caused by the varying deflection under varying pressures, each bridge is in section like a bowstring girder, the bow not being attached, however, to the string except at the ends; and, by connecting the intermediate space with the exhaust, the flat surface is little distorted by pressure, and does not partake of any deflection affecting the bow. This construction of Mr. Wilson's valve is due to Mr. J. Donaldson, M. Inst. C.E., and appears to answer its purpose well.

The packing rings of the pistons are of Perkins metal, four in each piston, in separate grooves. They are found to work much more quietly than the single wide rings usually adopted in marine engines.

The fan engine is similar to the one employed in the "Gitana." Two feed pumps are worked by a cast-iron four-thread worm on the engine shaft, geared into a suitable wheel of phosphor-bronze secured to a steel shaft, having cranks at the ends, to each of which a feed pump is connected. The ratio of the gearing in the worm and wheel is as 4 to 15. The feed pumps are 4 inches in diameter, with a 3-inch stroke. The engine room also contains a bilge pump, which is worked from the feed pump shaft; and an air-compressing pump, with a separate engine, for charging torpedoes. A donkey pump is fitted in the stokehole, by which the boiler can be supplied when the main engines are at rest.

The propeller is constructed with three blades, and is placed forward of the rudder. It is four feet 6 inches in diameter, and has a pitch of 6 feet.

The boiler is of the locomotive type, and has a total heating surface of 620 square feet, of which 56 square feet are contributed by the fire-box surface. The area of the fire grate is 18.4 square feet.

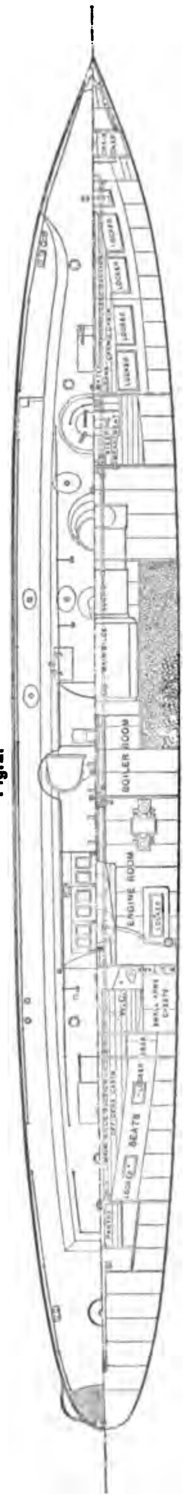


Fig. 2. FIRST CLASS TORPEDO BOAT.

The outer shell is 4 feet 5 inches in diameter, and 12 feet 6 inches long. It contains two hundred and five tubes 6 feet long, measured over the tube plates, and 1¾ inch in external diameter. The working pressure is ono hundred and twenty lbs.

An important feature in the boiler is the fire box. In the boilers of the smaller type of torpedo boats, the roofs of the fire boxes are stayed with ordinary longitudinal beams; but in the boilers of the larger type, where the fire grate amounts to more than 18 square feet in area, the roof of the fire box is stayed directly to the outer shell of the boiler, made flat for a width equal to that of the top of the fire box, to which it is connected by vertical stays. By this mode of construction, there is the advantage of adding slightly to the steam room, but this alone scarcely balances the extra weight of material used in construction. It is, however, more convenient for staying than the radial system when the outer shell is cylindrical over the fire box; and there is more elasticity to take up any unequal expansion between the fire box and the shell. The shells of the boilers are mostly of steel. In the earlier boats, the fire boxes were of copper; but in the boats built for the English Admiralty, the fire box has been constructed of iron, as the boilers are liable to be fed with salt water. At the same time, iron fire boxes possess greater strength than those of copper.

In order to extinguish the fire, in cases when it must be extinguished and cannot be drawn, a rose with an ejector is fitted, in constant communication with the sea, by admitting steam to which the fire may be extinguished in a very short time.

Provision is also made, by self-closing ash-pit doors, for preventing the return of vapor to the stokehole. A passage to the deck is also provided to facilitate the escape of the steam discharged in the event of a tube giving way.

Experiments were made at Portsmouth to ascertain the performance of the boilers of the first-class torpedo boats, the results of which are given in the annexed Table, I.

TABLE I.—BOILER TRIALS, FIRST-CLASS TORPEDO-BOAT No. 3.

Air pressure in stokehole....... inches	2	3	4	6
" " ash-pit.... "	1.47	2.29	3.26	5.25
" " furnace.... "	1.35	1.87	3.0	4.33
Temperature, feed-water.... Fahr.	53.5	57	54	56
" funnel.... "	1,073	1,192	1,260	1,444
Steam pressure (above atmosphere).... lbs	117	117	115	115
Coal consumed per hour.... "	925	1,177	1,472	1,815
" " " per square foot of fire-grate.... "	49	62	78	96
Water evaporated per hour.... "	6,530	7,770	9,320	10,840
" " per lb. of coal.... "	7.06	6.6	6.38	5.97
Evaporation per lb. of coal reduced to equivalent at 212° F. from 100°	7.61	7.08	6.81	6.41
Evaporation per hour per square foot of heating surface....	10.8	12.9	15.5	18.0
Coal used, Nixon's navigation. Ashes, 9 per cent.	H. M.	H. M.	H. M.	H. M.
Duration of experiment....	2 0	2 7	1 39	1 27

The influence of the pressure of air employed on the rate of evaporation and of combustion, and on the temperature of the gases leaving the boiler, is clearly manifested. The measurements of the pressure in the stokehole, ash pit, and fire box, show that of the initial pressure, the resistance of the tubes accounts for about seven-tenths of the whole, the resistance of the fire and fire bars being only about one-tenth. The loss on entering the ash pit appears too large, and the indicated deficiency of pressure under the bars is perhaps partly due to the comparatively high velocity of the air at this part of its transit. The pressure in the funnel, as measured, was sensibly equal to atmospheric pressure. The evaporative duty of the fuel in this boiler varies from 6.4 lbs. of water, evaporated with 6 inches of air pressure, to 7.6 lbs. with 2 inches, when reduced to the equivalent for feed water of 100° evaporated at 212°; and as the consumption of fuel per square foot of fire grate was 49 lbs. per hour with only 2 inches of air pressure, the results would have been of greater interest had lower press ure of air also been tried. The boiler, even at half-engine power, is worked too hard to give high duty; but to obtain the highest speed, when coal has only to be carried for a short distance, it is necessary to work the boiler above its economical rate of evaporation.

If it were intended to carry a supply of coal for great distances, no doubt more heating surface should be provided for a given power. The boiler made by Messrs. Clayton and Shuttleworth, and tried at Cardiff, evaporated (equivalent from and at 212° Fahrenheit) 11.8 lbs. of water per lb. of fuel, and gave the highest duty at that trial; but the evaporation per square foot of heating surface per hour was only 2.2 lbs., whereas the boiler tried at Portsmouth evaporated 18.0 lbs. (equivalent at 212°) per square foot of surface per hour, being fully eight times as much.

Amidships, the deck is raised, so as to give room to work the fire and the engines, the depth of the vessel otherwise not being sufficient for this purpose. On either side of this raised deck, the torpedo davits are fixed, and the torpedoes are so carried as to hang within the width of the boat, for security. Air for the fire is taken in at a cowl, situated just astern of the after bulkhead of the engine room, against which may be seen the disc of the blowing fan.

The deck forward is much rounded, so that any water that may come on board can run off with facility. The stepped section amidships partially gives the same result. It affords much better foothold than the rounded surface, which is very necessary for the men at this place.

The stern frame extends considerably below the rest of the vessel, and carries the rudder abaft the screw. This frame is a Bessemer-steel forging, carefully shaped to a long elliptical outline in horizontal section, parallel, of course, to the direction of its intended motion through the water, in order to reduce, as far as possible, its resistance. The boat is fitted with a bilge suction-pipe to each of the principal compartments. Indexes on deck show what communicating valves are open. In the section, Plate 4, Fig. 3, it will be observed that the boiler is placed lower at the forward end than at the fire-box end. The boilers, however, assume a horizontal position when the boats are at full speed, in consequence of the change of trim. This change amounts to about 3 feet 10 inches in 100 feet, according to the results of experiments on the "Miranda." By Mr. Froude's model of the "Lightning," at a speed corresponding to 19½ knots, it was shown that the vessel inclined 3 feet 5 inches in the same length, 100 feet; an inclination which does not differ much from that of the "Miranda."

SECOND-CLASS TORPEDO-BOAT.

This boat is 60 feet in length, with a beam of 7½ feet. The draught is 12½ inches forward, and 3 feet 4 inches aft. The displacement is 10.6 tons.

The engines are compound, surface-condensing, and work up to about 112 indicated HP. The cylinders are 7 inches and 11 inches respectively in diameter, with a stoke of 8 inches. The air pump, operated by levers, is 7 inches in diameter, with a stroke of 2 inches. Two feed pumps are worked by worm and wheel, as described for the first-class boats.

The circulation of the water in the condenser is effected entirely by an apparatus, by which the external motion of the water when the boat is moving is utilized. An ejector is also fitted for removing air from the water space of the condenser, which is partly above the load water line. By this apparatus sufficient circulation can be maintained, when the boat is at rest, to condense any steam that may be required to be condensed in order to prevent its escaping into the air.

A small engine is used for blowing the fires, the same as described for the first-class boats; but it is made to drive two pumps, which can be connected when required.

The boiler is of the locomotive type, and has a total heating surface of 198 square feet, of which 22 square feet are supplied by the fire-box surface. The area of the fire grate is 6.3 square feet. The outer shell is 3 feet 1 inch in diameter, 7 feet 7 inches in length, and contains one hundred and twelve solid-drawn brass tubes, 48½ inches long, and 1½ inch in external diameter. The working pressure is 120 lbs.

Fig. 3 represents the sheer draught of

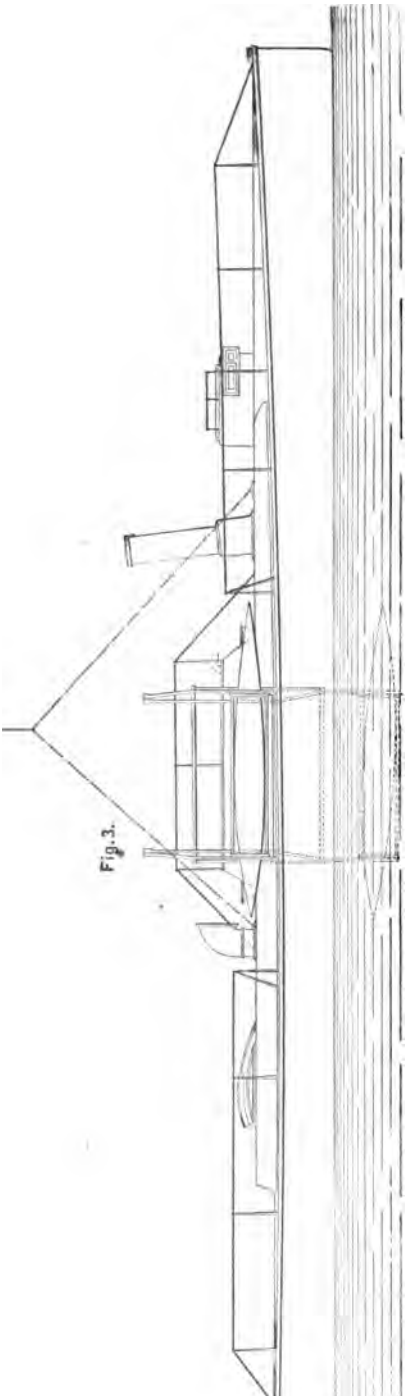


Fig. 3.

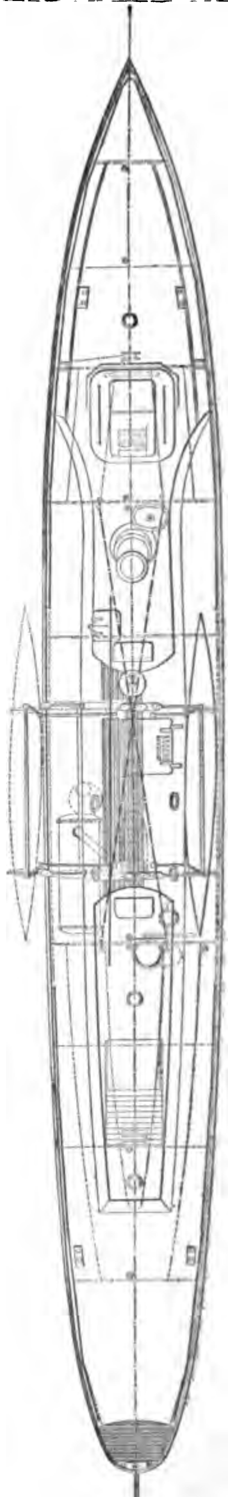


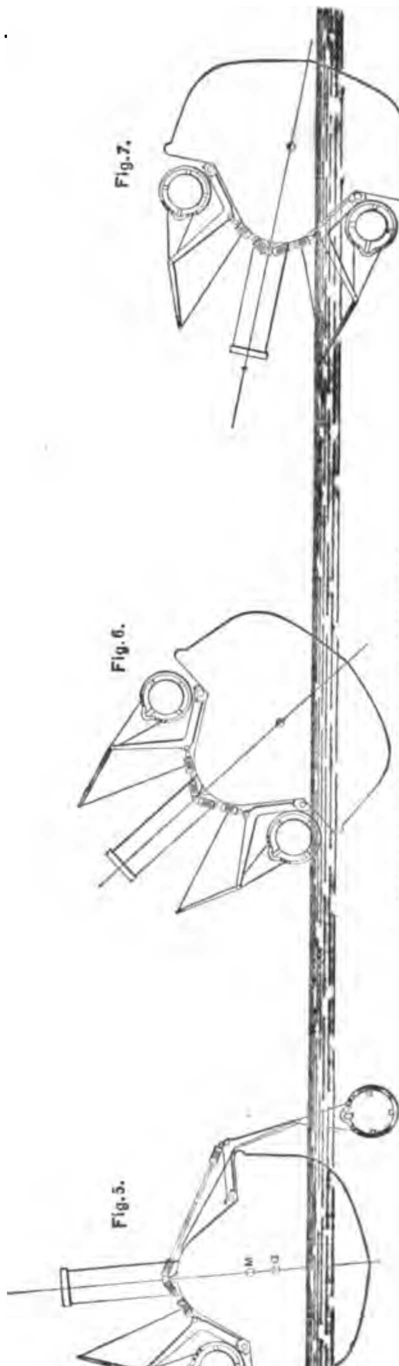
Fig. 4.

the boat, with a "Whitehead" torpedo in davits, as carried. The boat is also seen in Fig. 4. It is divided into six water-tight compartments, and is subdivided up to a level considerably above the water line, by half bulkheads. The vessel is steered from forward. The conning shield over the steering wheel is of 4-inch steel plates on the forward side.

Figs. 5, 6 and 7 represent the second-class torpedo-boat in cross section, and are intended to illustrate its stability. Fig. 5 shows the inclination due to the absence of one torpedo when the unbalanced weight of the other inclines the boat to about 5¼°. Fig. 6 shows the boat inclined until the righting force has become a maximum, which happens at about 42.° Fig. 7 gives a section of the same boat heeled over until the stability is just vanishing, when the angle is about 79°. This angle comprises a large range of stability, which is favorable to the safety of the boat.

The boiler and engines being, in the second-class torpedo-boats, contained in one compartment, there is some advantage in point of simplicity over the larger type. But this disposition involves so large a compartment as would endanger the boat if it were filled with water. It has therefore been decided to separate the engine from the boiler by a bulkhead, in the new boats of this class now being built. Any one compartment in these boats may become flooded, and yet an ample degree of buoyancy would remain.

These boats are designed to be carried on board ship, and they require to be slung overboard complete and ready for use. This condition involves their being subjected to considerable stresses. To illustrate the effect of their being thus suspended the data for the curves, Figs. 8 and 9, have been calculated. In these diagrams, the weight of the vessel is represented in amount and distribution by the area contained between the base line X Y, which also represents the length of the vessel, and the curve lines WWW. The points of support, when suspended, correspond to the points P_1 P_1 in the diagram; and for simplicity the vertical components only of the forces acting through these points in this case are at first taken. The bending moment at any section of the hull is



SECOND CLASS BOAT. CURVE OF STABILITY

represented by the distance of the line M M M from the base X Y, the shearing forces being, in the same way, represented by the distance of the line S S S from the same base line. When the oblique forces are considered, and the slings take the lines 1, 1, or 2, 2, the bending moments for sections between P and P_1 will be increased as shown by the line M_1 or the line M_2.

SECOND CLASS BOAT.
CURVES OF SHEARING FORCES AND BENDING MOMENTS
WHEN SUSPENDED.

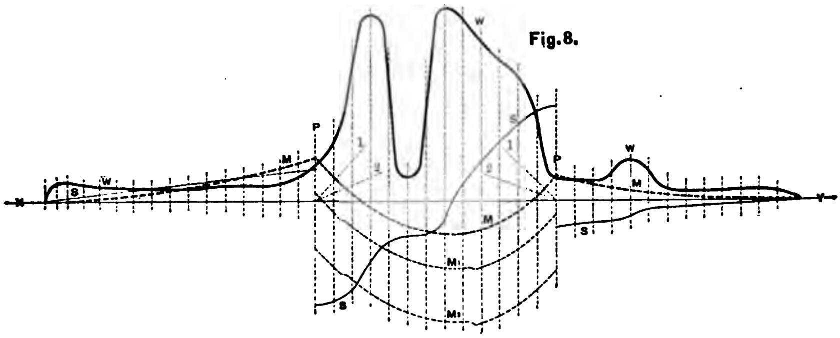


Fig. 8.

The curves M and S S, in the diagram, Fig. 9, represent the bending moments and shearing forces to which the hull is subjected when floating in still water, where the area between the line B B and the base line represents the supporting force, or displacement. The line L L. represents the curve of loads, or difference between the curve of weight W W and the curve of displacement B B at any point. The ordinates for the line B B and M M being drawn to the same scale, it is evident that the greatest stress to which the boat is subjected on being lifted, is only a small part of its ultimate power of resistance; the maximum stress on the material being about 7,000 lbs., or 3.14 tons per square inch.

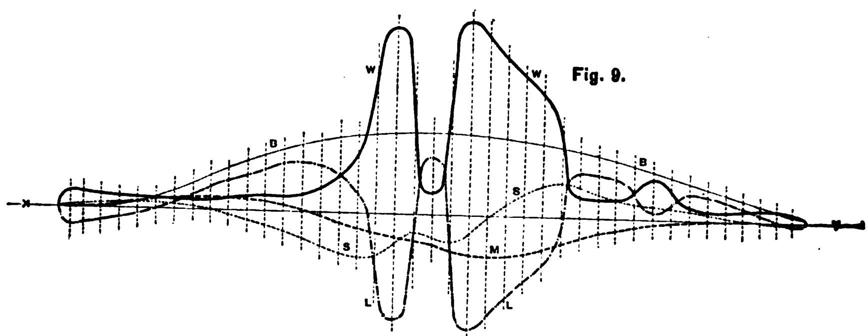


Fig. 9.

CURVES OF SHEARING FORCES AND BENDING MOMENTS WHEN AFLOAT

CONCLUSION.

A few examples of the weight of hulls in percentage of displacement, taken principally from sea-going vessels, with the co-efficient of fineness of form, are given in Table II. (p. 365.) By comparing the hulls built by the author's firm it will be seen that the weight has not been unduly reduced; for although they are lighter, their relatively short lengths afford great advantage for relative strength.

A selection of practical instances is given in Table III. (p. 366), to show by contrast the progress that has been made in concentrating power in a small compass, and at the same time reducing the weight of the machinery and of the boilers. The quantities in the seventh column of the Table—cylinder capacity per

TABLE II.—PROPORTIONATE WEIGHT OF HULLS.

Name of vessel.	Percentage of displacement		Co-effici'nt of fineness.
	Weight of hull.	Weight carried.	Immersed volume. / Midship section × length.
	Per ct.	Per ct.	
Circular ironclads....	20 to 22	78 to 80	0.780
Iron merchant ships.	30 " 35	65 " 70	—
H.M.S. Bellerophon..	49	51	0.698
H.M.S. Inconstant...	51	49	0.614
H.M.S. Devastation..	31	69	0.766
H.M.S. Iris..........	32	68	0.548
H.M.S. Inflexible....	34	66	0.721
Lightn'g torpedo boat	33	67	0.601
1st-class " "	33	67	0.583
" with ram bow.	33	67	0.552
2d-class torpedo boat.	30	75	0.591
Miranda (yacht).....	35	65	0.561
Gitana (yacht).......	33	67	0.662

indicated HP.—are deduced by dividing half the volume swept by the pistons in one revolution by the indicated HP. They are approximate measures of performance relatively to the bulk and weight of the engine, irrespective of the boilers.

Table IV. (p. 366) contains some additional comparative results of the performance of large steam vessels of the navy, and the yachts and torpedo boats before described.

On comparing the contents of the Tables III. and IV., it appears that the "Gitana" presents the lightest machinery in proportion to indicated HP., weighing only 43½ lbs. per indicated HP., or a little over one-eighth of the machinery of the Holyhead mail boats, and only one-fourteenth of that of the American paddle river boats, the "City of Boston" and the "City of New York." Correspondingly, the volume of cylinder per indicated HP. of the "Gitana" is but one-fourteenth of that of the Holyhead boats, and only one twenty-third of that of the American boats. In this respect, the "Miranda" excels even the "Gitana," having only 6.3 cubic inches of cylinder capacity per indicated HP., or little over one-third of that of the "Gitana."

The consumption of fuel in the torpedo boats has been approximately measured, and is about 3.9 lbs. per indicated HP. for the first-class boats when developing 340 indicated HP., and 3.5 lbs. for the second-class boats at 112 indicated HP.

From the last column of Table I. it appears that from 1 square foot of fire grate 28.4 indicated HP. were developed in the "Gitana"; whilst, in the last column but one, 1 indicated HP. was developed for 1.33 square foot of heating surface, in the first-class torpedo boats.

With regard to the relative consumption of fuel for each indicated HP., it is apparent that the lighter machinery consumes more than the heavier machinery. But the excess of consumption is due, not to comparative lightness, but to the fact that the boilers are proportionately overworked, as is clearly proved by the high rates of consumption of fuel per square foot of fire grate. The ratio of expansion used in the torpedo boat engines seems, perhaps, less than desirable, but the gain from expanding more than five times with the pressure used, would be very limited, whilst the weight of engines would be materially increased.

In comparing, in Table IV., the performance of small vessels with large ones, the common formula $\frac{V^3 D^{\frac{2}{3}}}{I.H.P.} = C$, is convenient and suitable; for if similarly formed vessels of different dimensions are propelled at what Mr. Froude has called "corresponding speeds" (speeds proportioned to the square root of their linear dimensions), the power required varies in such a manner as to give a constant value to this fraction, if the effect of the different proportion of surface friction to the whole resistance may be neglected in the comparison; and, as the increased proportion of surface friction in small vessels has the effect of reducing the value of the constant C, this formula cannot be supposed to favor the particular kind of craft under discussion. The high value obtained by No. 10 torpedo boat, Table IV., is worthy of remark; but it should be noted that this boat had the advantage over others of its class, that no bilge keels were fitted, and the stern frame did not extend below the propeller boss.

TABLE III.—RELATIVE PERFORMANCE AND WEIGHT OF STEAM VESSELS, AND LOCOMOTIVES.

Date.	Name of vessel.	Fuel per square foot of fire grate per hour.	Boiler pressure.	Revolutions per minute.	Speed of piston in feet per minute.	Indicated HP.	Cubic inches of cylinder per indicated HP.	Weight of propelling machinery, including boilers with water. Per Indicated HP.	Weight of propelling machinery, including boilers with water. Per cub. inch of cylinder.	Heating surface per indicated HP.	Indicated HP. per foot of fire grate.
		Lbs.	Lbs.					Lbs.	Lbs.		
1855	City of Boston and City of New York..........	—	35	20.0	480	1800	403.0	606.0	1.50	—	—
1857	Persia..............	—	25	15.0	360	4950	457.0	498.0	1.08	—	—
1861	Holyhead mail boats.	—	—	22.0	286	4751	248.0	318.0	1.34	—	—
1878	H.M.S. Inflexible....	21.0	61	73.2	585	8483	185.0	420.0	2 26	—	—
1829	Rocket, locomotive..	36.0	—	143.0	393	22	73.0	286.0	3.98	—	—
	Modern locomotive..	80.0	120	240.0	880	—	—	—	9.80	—	—
1872	Miranda (yacht).....	—	120	600.0	800	64	6.3	62.8	10.00	1.84	16.2
1876	Gitana (yacht)......	138.0	120	320.0	850	460	17.3	43.5	2.52	1.53	28.4
1877	First-class torpedo boats..... (lightning class)	100.0	120	440.0	880	455	12.0	57.7	4.80	1.33	23.4
1879	Second-class torpedo boats.....	60.0	120	600.0	800	108	9.9	81.6	8.26	1.82	16.6
1880		78.5	130	650.0	866	150	9.1	66.5	7.27	1.66	23.1

TABLE IV.—RELATIVE DISPLACEMENT AND PERFORMANCE OF STEAM VESSELS.

Name of vessel.	Date.	Length on W.L.		Displacement.	Indicated HP.	Speed in knots per hour.	$\frac{V^3 D^{\frac{2}{3}}}{I. HP.}$	Blast in ins. of water.	Revolutions per minute.	Steam pressure in boiler.	Receiver.	Vacuum in condenser.	Fuel per indicated HP. about.
		ft.	in.	tons.	I. HP.	knots.	constant	ins.	turns.	lbs.	lbs.	ins.	lbs.
Miranda............	1872	45	6	3.7	64	16.20	160.0	—	600.0	120.0	—	—	—
Gitana.............	1876	86	0	29.0	460	20.75	183.0	4 to 6	320.0	120.0	—	—	—
1st-class torpedo boat No. 1	1877	81	.0	28.7	400	18.55	150.0	—	350.0	120.0	35.0	25.25	—
" " " 6.	1879	83	9	32.43	425	20.00	191.5	5	420.0	120.0	36.0	25.0	3.92*
" " " 10.	1880	88	3	29.73	460	22.01	223.0	5	438.0	123.0	36 0	24.5	—
" " " 10.	1880	88	3	32.5	469	21.756	224 0	5½	443.0	133.8	40.5	23.8	—
2d-class torpedo boat.	1879	58	4	10.6	108	16.51	184 0	3½	600.0	120.0	38.0	24.5	3.51
" "	1880	60	10	10 9	150	17.645	180.0	3	653.0	131.0	41.3	22.4	—
H.M.S. Inconstant..	1869	339	0	5,328.0	7,361	16.513	186.0	—	74.5	30.4	—	25.3	3.25
H.M.S. Inflexible...	1878	324	0	9,515.0	8,483	14.74	169.0	—	73.26	61.0	—	26.5	2.06
H.M.S. Iris........	1878	301	6	3,290.0	7,556	18.573	189.0	—	97.2	65.0	—	2.7	2.75

* The consumption 3.92 lbs. took place with a first-class torpedo boat, when indicating 340 indicated HP.
† The consumption 3.51 lbs. took place with a second-class torpedo boat, when indicating 118 indicated HP.

DISCUSSION. (ABSTRACT.)

MR. THORNYCROFT asked permission to add a few words with reference to the vibration of the boats at high speed. He did not mean to say it was necessary that there should be vibration at high speed; but each boat had a particular vibration due to the strength and weight of its structure, and if the engines were run at the same number of revolutions as the boat would make beats, there would certainly be a considerable vibration of the hull. It was generally practicable to run engines at a higher speed than the natural period of the boat's vibrations. In the case of one of the Government torpedo boats, the "Lightning," it had recently been ascertained that the boat vibrated considerably at about three hundred and sixty revolutions per minute, and that it continued through some little range. It was found desirable to alter the propeller, so as not to run at full speed, at that particular speed of the engine.

Mr. A. F. Yarrow inquired whether the author had any data touching the consumption of fuel by his vessels for long distances, as that was becoming a matter of considerable importance. He might mention that in boats 100 feet in length, built by his firm, having a displacement of about 40 tons, 1 ton of coal would last for a run of 100 miles at a 10-knot speed.

As to the pitch and size of propellers, he had found that in very fast boats a propeller giving anything less than 12 or more than 27 per cent. slip was bad. In propellers of large diameter there was, at very low speeds, a negative slip amounting to 1 per cent., and in some cases 1½ per cent. He believed there could be no possible mistake about this, as it had been confirmed by repeated experiments. He found that if a screw gave a negative slip at a low speed it was a bad propeller for all speeds. In well-proportioned screws the slip increased with the speed up to 18 knots per hour; above that it slightly diminished.

It was the practice of this firm to use two-bladed screws, as they believed there was a slight gain over three-bladed ones. It had often been said that, probably from using a two-bladed screw, their boats vibrated more than they otherwise would do, but this he believed was not the case. He thought if a two-bladed screw was well immersed and perfectly balanced, there was really no vibration whatever due to it. The vibration was mainly caused by the unbalanced vertical movements of the engine. This had been ascertained by removing the propeller from one of their boats, and then working the engines. The vibration was precisely the same, in degree and in kind, as if the boat was traveling. Also, in a torpedo boat 86 feet in length, when the engines were making two hundred, four hundred, six hundred or eight hundred revolutions per minute, the vibration was excessive, but at intermediate speeds of three hundred, five hundred and seven hundred, the vibration ceased altogether, showing that there were speeds at which these boats must not be allowed to run for any length of time, since serious vibration meant excessive wear and tear.

He thought any discussion on this subject would be incomplete unless reference was made to the Herreshoff torpedo boat, as, although it proved a failure, it still combined a great number of novelties, and was the most ingenious and interesting vessel of its class that had ever been brought out, and did infinite credit to its designers.

There was one point to which he would specially allude, viz., the position of the propeller, which was under the bottom of the boat. This position had its advantages and disadvantages, and his firm took an early opportunity of testing the value of it in one of their large boats. They selected for the purpose a boat of the usual size and power to make a fair comparison. They found. contrary to expectation, that instead of obtaining an increased speed, due to the propeller working in more solid water, there was a loss of speed. In fact, it was ascertained by comparing it with other boats having the propeller placed in the usual position, that there was a waste of 80 HP. out of 450 HP.; that was to say, with the same power, the loss in speed was about 1½ knot per hour. He believed this might be due to the propeller, being under the bottom, causing a stream of water to flow with considerable velocity in the opposite direction to that in which the vessel was traveling, inasmuch as the boat was passing through water partly at rest, and partly having motion in the opposite direction, causing increased skin friction.

It had become a question in what way machine guns affected torpedo boats. He estimated that a weight of 10 tons, distributed over the deck and sides of a torpedo boat 100 feet long, would give ample protection against the guns at present in use; that was at a distance suitable for firing the Whitehead torpedo. As experiment demonstrated that, in a 100-feet boat having 40 tons displacement, for every ton additional carried there was a reduction in speed of nearly

½ knot; it followed that the extra 10 tons weight represented a loss of speed amounting to 2½ knots; and it rested with naval authorities to determine whether the fraction of speed or the protection was the more desirable.

There was only one small point in which he differed from the author, who stated that the most favorable position for the propeller at high speeds was astern of the rudder. If, at the same time as placing the rudder aft of the screw, the propeller itself was bodily moved nearer to the stern of the boat, then he was prepared to admit that there would be a reduced efficiency, but this reduced efficiency would be due to the altered relative position between the propeller and the stern, and not really to the rudder. Not only did he consider there was no loss by the rudder being placed aft of the screw, but he was of opinion that there was a positive although but a small gain. The reason for believing that the rudder being aft of the screw added to the efficiency, was because it had a tendency to check the rotary motion of the water.

Some time since his firm tried some experiments with a propeller or turbine, similar to what the Hon. R. C. Parsons, Assoc. M. Inst. C.E., and others had advocated, and which consisted of a ring provided with blades formed as screw blades. This propeller was placed in the usual position at the end of the shaft. Aft and close to this, there was another fixed ring, with guide blades in it curved in such a manner as to take up and utilize, for the propulsion of the vessel, the rotary motion imparted to the water. They had tried some experiments on a boat with this arrangement in three forms :—in the form just described; also by substituting straight guide blades for the curved ones; and also without guide blades. As might have been expected, without guide blades the efficiency was very inferior; but whether the guide blades were straight or curved was a matter of little importance, showing that guide blades (although straight) added to the efficiency of the propeller. From these experiments, he contended that the same thing held good, but to a much smaller extent, with an ordinary screw, in which case the rudder acted the part of a guide blade.

Again, in confirmation of this argument, he might mention that his firm built two boats, one with the rudder aft of the propeller, and one with the rudder forward of the propeller, but the relative positions of the propeller and of the stern were the same. The result was that the boat having the rudder outside the propeller, gave a trifle higher efficiency for the same HP. It must be borne in mind that, in dealing with this question, the rudder was assumed to be made so as to offer the least possible resistance; and his firm always made their rudders out of a solid steel forging exceedingly fine at the forward and after edges.

The author had stated that in the boats supplied by him to the English government he was in the habit of using iron for the fire boxes, and that they possessed greater strength than if made of copper. It was the usual practice of his firm to use copper and not iron where a very high rate of combustion was required, because they thought it a more suitable and reliable material when subjected to intense heat and rapid changes of temperature; their impression being that iron for such a purpose was somewhat treacherous. It would be of great interest to ascertain the comparative merits of copper fire boxes and iron fire boxes, also of iron tubes, brass tubes, or iron tubes with copper ends, as it appeared the choice lay between these three. Concerning this question he believed his firm was not alone in having had considerable trouble in keeping the tubes in the fire box tube-plate tight. It was one of the greatest difficulties they had to contend with. About three years ago, when they were greatly troubled in this respect, their attention was drawn to the ovaling of the tube holes by Herr A. Waldfogel, chief engineer of the Austrian navy, and also by Mr. E. J. Cowling Welch. They at once set about trying some experiments to test exactly what was going on with the tube plate when the boiler was in steam. The first row of stays next the tube plate was removed from one boiler, and other stays substituted, fastened to the copper fire box as usual, and passing through stuffing boxes on the outside shell. There was a nut on the end of each stay bearing upon the gland of the stuffing box in case a tensile strain came upon it. When the boat was steaming and there was a fierce fire inside, all these stays were relieved from tension, and in fact the stays had moved through the stuffing boxes to the extent of from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch. It was exceedingly interesting to remark how suddenly, when the fan inside the stokehole was stopped and started, the stays moved in and out of the stuffing boxes, showing, in this class of boat, where the combustion was constantly varying, what unfavorable strains must come on the tube plate if the stays next the tube plate were rigid. In one case, the extension of a tube plate was $\frac{3}{8}$ inch in the first run. It was now their practice to fit the first complete row of stays in copper fire-box boilers, with stays arranged in such a way that they could expand and contract freely, as was done by some locomotive builders on the Continent. He might mention also that of late they had made a drop in the fire-box top of 4 or 5 inches, so that an area of at least three-fourths of the fire-box top was on a lower level than the portion next the tube plate. This allowed a little longitudinal movement, and at the same time gave a greater depth of water over the fire-box top, which in small sea-going vessels he believed to be desirable.

Mr. J. R. Ravenhill said, although Mr. Yarrow had given a most interesting account of his experience, he had stopped short in his explanation. There could be no doubt that the speeds attained by the boats of Messrs. Thornycroft and Messrs. Yarrow were very nearly alike. Mr. Yarrow had alluded to a difference in the form of the propeller, but he had not mentioned certain details of his arrangements differing from those shown in the engine exhibited by the author. Mr. Ravenhill would therefore venture to supplement what Mr. Yarrow had stated, so that the members might have before them the means by which such high speeds were attained. Messrs. Yarrow attached the main engines alone to the shafting. For working their air pumps and feed pumps, an auxiliary engine was employed, and by this means ran them at a much less speed than was adopted by Messrs. Thornycroft, whose practice had been to run them at a greater number of revolutions. There was barely a limit to the number of revolutions that might be run, the engines being put direct on to the shafting, and driving only the propeller. It was a movement in the right direction, because there was no doubt that, by piston speed, weight might be saved. The weight of the machinery in the torpedo boat was, as had been stated by both makers, a most important element. It might be that they could not do very much more than they had done with reference to the engine, because they made so many parts of steel. There was very little cast iron left for them to cut and pare on. In his opinion, there was a considerable advantage in having the air pumps distinct from the engines. They could be started with a vacuum at any time by taking care to have the smaller engines at work first. Any one who had been accustomed to see these quick-running engines well handled would fully understand the advantages to be obtained in that way. It was the boiler to which attention would have to be directed for the further saving of weight. The weight of the locomotive boiler was considerable—probably 30 per cent. of the whole. The water-tube boiler had hitherto not answered all expectations. Two or three different forms had been tried, but he believed that before long some form of water-tube boiler would be found essential. Engineers who were paying attention to that class of machinery could not do better than bestow great attention on that point, until the right kind of boiler for torpedo vessels was discovered. The author had, in Table III., alluded to the Holyhead boats, and there were one or two points in connection with the Table to which Mr. Ravenhill desired to call attention. The indicated HP. was clearly that of the "Leinster." The revolutions per minute were stated as twenty-two, but when the vessel was indicating the power quoted in the Table, the revolutions were 26$\frac{1}{4}$ per minute, which would give a speed of piston of 354$\frac{1}{2}$ feet per minute. The boiler pressure was 25 lbs., and the indicated HP. per foot of fire grate 16.7. The improvement shown was no doubt very marked, but he should have been glad if the author had supplemented his figures by stating what was the performance of some of the merchant steamers at the present time. A large vessel recently, when on trial, had a piston speed of over 800 feet per minute for a considerable time, and her ocean speed was to be 780 feet per minute.

Admiral Selwyn had been delighted to listen to the exposition which the author had given of some of the advantages that had accrued to the world by the study of principles of which he was the first exponent: how light and yet powerful engines should be made, how light and how handy vessels could be constructed, and how fast they could be driven; which to a naval man involved the whole question of success at sea. He had given a dissertation on the work accomplished, the result of long years of observation reduced to successful practice. Some of his conclusions might be open to question. Admiral Selwyn might demur to the first conclusion, that if better results than had been obtained were desired, it would be necessary to resort to larger boilers. He should be disposed to ask whether the fuel employed could not be changed, and whether it was necessary to provide larger boilers, which instead of giving 11 lbs. of evaporative duty under the plenum to which they were subjected of air-pressure and consequent oxygen blown in to promote combustion, gave an economy much less than desirable, and than what he had said had been found in the same boilers under their natural draught. That was the solution of the difficulty, but not in the most philosophical way. He should have desired to see some reference to the proportions between the strains and the margin of the load—to see how nearly a safe load on each part of an engine and a boiler had been attained, and whether a continuance of work under those loads could be relied on. He likewise wished to advert to the mode of propulsion by screws. His recollection extended back to the first screw known in the country, the Archimedean screw. It was not, however, absolutely the first, because that was exhibited more than two hundred years ago by a working shipwright, and he believed was still to be seen in Plymouth yard. No remarkable advance had been made in screws, A screw, as the author had well said, would give a very fair result, seven-tenths of the power applied to it, so long as no air came to it; but the instant a screw vessel was taken into the disturbed ocean, air was an inevitable accompaniment. The vessel would pitch in nine cases out of ten, and the screw as a propeller was then in the inefficient condition which the author had described, about 50 per cent. of the power being wasted. He thought it would be necessary to go a little further and contemplate a different condition of the screw altogether. With regard to the Herreshoff boiler, referred to in the paper, although it was doing wonders in the way of evaporation, as might be expected where a small quantity of water was subjected to a very high heat in a coil, it was not reliable unless distilled water was used. The Herreshoff coil was one of the oldest inventions on the subject, having been produced by the grandfather of a celebrated inventor in high pressures many years ago, but it was given up by him as not being an efficient instrument. Engineers ought not to be misled either by the Herreshoff boiler, or by the position of the screw. This position had been described as occasionally causing loss instead of gain. If the screw were put sufficiently deep down to run in the undisturbed water surrounding the vessel, then, like all other propelling instruments, it would give its best effect; but if the velocity of the vessel were increased, and the accompanying skin of water increased also in depth, there might be a loss instead of a gain. As in the case of all screws, in whatever position, it depended entirely upon the speed of the vessel, and the position of the screw relatively to that speed. No such instrument would succeed unless it was tried under all conditions. It would give a great effect when the speed of the vessel was not such as to carry the skin of the water round the vessel deeper than the upper part of the blades; it could give no effect at all, or a negative effect, the instant it was comprised in the current carried by the vessel which the late Mr. Froude had defined. Sir William Thomson had an objection to the Berthon log or speed measurer. Many persons had been charmed with the idea of having an instrument like a barometer in the cabin to measure the speed of the vessel. It was thought that if a tube were taken out of a vessel which showed the pressure on the bottom of it, in that way the measurement of speed could be obtained; but Sir William Thompson's experiments had shown that unless the tube were prolonged for each speed of the vessel below the skin of the vessel, the result would be worthless. It was necessary to have it in undisturbed water, which it was not possible to get under ordinary conditions. With regard to the question of engines, overhung as the cylinders were now in most of the compound engines adapted to torpedo boats, he could recognise the fact that it was sufficient to provide for vertical pressure in smooth water; but he denied the fact that if the vessel were to be considered subject to the ordinary motions at sea, it was safe with any large sized vessel to rely on such a provision for unison with working surfaces. If the cylinders were a considerable portion of the weight, the engines suported only vertically, and stayed to a yielding skin, a motion of two inches from side to side, such as he had sometimes witnessed, would throw strains which he was certain no constructor had ever calculated, on every part of the engine. He was not surprised, under those circumstances, that many parts calculated according to the usual law of strains had been unable to bear the stresses thrown upon them. Reference had been made to the compound engines of a United States revenue steamer, in which the cylinders were thorougly steam-jacketed, with the steam at 82 lbs, per square inch initial pressure. What was meant by being thoroughly steam-jacketed? It meant a heat and a pressure superior to that at which it was intended to use the steam inside the cylinders; and 82 lbs. pressure did not involve a very high degree of heat kept up. The losses by external radiation might well be equal to the loss by radiation from 82 lbs. steam; but dealing with much higher pressures and higher temperatures, enormous values might be got out of steam-jacketing, and if it was ignored it was impossible to conduct the expansion which ought to be due to high pressures, and which gave them their chief value with any good result. During some recent experiments in America, the steam-jackets were considered useless, and had been shut off, and the engineers were puzzled to find that there was much condensation of water in the cylinders, because the jackets had been carefully cut out, and the steam was left to go in at high pressure and to on dense in the cylinders to form water, tasking the whole of the work to get rid of the water, so that the economy fell much below what it ought to have been. Reference had been made to Perkins metal. He was interested merely in a scientific way, in knowing whether Perkins metal succeeded in preventing all scoring of cylinders at high temperatures and at high speeds of the piston. If it did, he thought the author would acknowledge that it was of no use to compare it with any other metal or any other rings. If, in the absence of lubrication, which had always been a difficulty, the Perkins metal showed an absence of scoring on the cylinders at the highest temperatures of steam, and the highest speeds of the piston, progress would be much faster than would otherwise be possible. It was not sufficient to consider the question that they worked much more quietly than single wide rings; the question was whether wide rings would work at all under those conditions? That was the interesting point to engineers. With regard to the water evaporated per lb. of fuel, he had long been an advocate of condensed fuel, by which an advantage could be gained that never would be secured by forced combustion. If combustion were forced, pouring in oxygen and nitrogen, all of which nitrogen must be heated up, and all of which heated gas was lost, doing no good whatever, so favorable an effect would never be got as could be obtained with the condensed fuel which could evaporate a large quantity of water without undue draught. Engineers might do away with the chimney draught, and not only be without a plenum in the stoke-hole, but not even have a vacuum in the funnel, or anything approaching it. There could thus be obtained an evaporation of 60 lbs. of water by a consumption of 1 lb. of fuel, plus 1 lb. of steam. If the chemical laws of combustion under which it was done were understood, it could be done again and again, as he had seen it done with a common Cornish boiler. There was one point which had especially struck him in connection with the paper. If the author and Mr. Yarrow could build boats which had an angle of vanishing stability of 79°, it was surely possible, with ironclads, by resorting to the same means, to obtain a much greater vanishing angle of stability than 45°. That was of the utmost importance to the navy of England. Ironclads were being built which did not command the confidence of those who sailed in them. It was a fashion to say that everything was done for the best, and that it was the best that could be done; but that, he felt sure, was not a principle that would commend itself to an assembly of engineers. Nothing was done while anything remained to be done, and so long as there was a possibility of increasing the stability of vessels, so long that increase should be sought. It was to be gained by a change of form, by amending the tonnage laws which at present limited the forms of merchant ships, by improving the shape above water without much affecting the midship section or the frictional surface, and therefore but slightly the speed of the vessel. If constructors would in many things follow the lead which the author had given, they would be able to make improvements, and naval architects of the highest class would gain very greatly, and obtain a title far beyond that which any Institution could give them to the confidence of their fellow countrymen.

Mr. James Wright, C.B., Engineer-in-Chief of the Navy, observed that in the remarks he had to make there would be little that was new, but he thought it only right to say a few words in reference to the experience of the Admiralty of the machinery supplied by the author of the paper. As to the engines, which had been severely tried, they had answered in every respect, and there had been no mishap of any kind—indeed there had not been even a case of hot bearings on the trials, a common thing in the trial of marine engines in the present day. When he stated that engines like those exhibited had been run for three hours continuously at over six hundred revolutions per minute, and for shorter periods six hundred and fifty, he thought that was saying a great deal. Indeed it was only fair to the author to say that, as far as the engines were concerned in the boats supplied by him to the Admiralty, they were as nearly as possible perfect for the purpose for which they had been designed. With regard to the boilers, he could not give quite the same unqualified testimony. They had done very well on the whole, but there had been some trouble with leaky tubes. The first boilers has brass tubes, and they leaked very much; then iron tubes were tried, but they leaked too. That was really the only structural defect encountered; the experience of locomotive engineers would no doubt help to overcome the difficulty. The other matter was that of the boilers priming. The author had mentioned that boilers of the locomotive type in torpedo boats should have larger steam room than ordinary locomotive boilers. He thought the author would have to go farther, and give more space between the tubes—in fact to make the boilers altogether rather more roomy. They were of course at a disadvantage compared with the ordinary locomotive boiler, because it was not always possible to get pure fresh water; the water had to be evaporated and sent through the engines over and over again; and although precautions were taken to keep out the oil as much as possible, there was no doubt that after a time the water became greasy, and that seemed to set up priming. That, however, could only be regarded as an occasional difficulty which would, no doubt, be removed in time. In other respects the boilers had been satisfactory. In Table III. the author had taken the "Inflexible's" engines as a type for comparison with the torpedo boat engines, and he had given the weight at 420 lbs. per indicated HP. The 420 lbs. had been taken upon the original weight when the ship was designed seven years ago; as completed, the actual weight was only 360 lbs., and the HP. so obtained was without any artificial blast, simply by the natural draught of the boilers. He merely mentioned the circumstance to show that modern marine engines stood rather better in relation to the examples of other engines given than the Table would indicate. To confirm what he had stated, he might mention that the weight of the "Nelson's" machinery was 360 lbs. per indicated HP., and that of the "Iris" only 320 lbs. Those weights had been taken upon trials with the natural draught; if the draught had been forced to a moderate extent, as it usually was in such trials, by the steam blast, no doubt the weight would have been but a little over 300 lbs. Of course, in any such system of machinery as that described, the question of forced combustion was an all-important one, and no doubt the author had been quite right in adopting the best method. Some persons had objected to the method on the ground that it would have a bad moral effect on the stokers. It was thought that men would not readily be got to work the fires when shut up in a closed stoke hole without ready means of escape. He was glad to say that no such difficulty had as yet been experienced, and he did not think that it was likely to be. There was really no danger incurred. In all cases appliances were provided (first introduced, he believed, by Mr. Yarrow) for preventing any injury to the stokers by the bursting of a tube; and the author had advised another arrangement for the same purpose. In the very improbable case of a boiler explosion, he did not think it would be of much matter to the stokers whether the stoke hole was closed or not. With a view, however, of seeing whether any method of forced combustion approximating in efficiency to the one with the stoke hole under pressure could be obtained, so as to work with an open stoke hole, a number of experiments had lately been made in the dock yards, some with steam jets and some with blowing the air into the funnel. Forced combustion by the steam jet on the old system was very wasteful. Usually, in trials of ordinary marine engines, there could be got with the steam jet in the funnel an increased combustion of coal from 40 to 50 per cent. over what was obtained with the natural draught; but it was very wasteful, the increase in power not exceeding 15 per cent. over what was obtained with the natural draught. Of course, the steam jet could not be used for torpedo boats, as it would lead to the waste of fresh water in them. Trials were made in No. 3 torpedo boats (of which the author had given the evaporative results), using the same fan, but blowing air into the chimney. The fan was driven so hard as to give a pressure equal to 12 inches of water per square inch and upwards. Nozzles of different sizes were tried, from 2 inches up to 5 inches in diameter, such as the blast nozzles of locomotive engines; a slit ring was also tried, but the results were disappointing. In fact, the best result which was with a nozzle 3½ inches in diameter, was no better than what was obtained in the ordinary boiler with the natural draught; and it was not one-half what was obtained with two inches of air pressure in a closed stoke hole with the same boiler. The consequence was that he thought the idea must be given up of using any other means than the closed stoke hole. It was not a new thing; he believed it had been employed a long time in America, where dull-burning anthracite coal required a great deal of forcing; it was also gradually being introduced into France and in various parts of this country, for large ships. Altogether, it appeared to be the best system that could be adopted. About three years ago, observing the success that the author and Mr. Yarrow had obtained, the Admiralty had ordered from Messrs. Humphreys of Deptford a set of machinery on this system for the torpedo ram, "Polyphemus." The engines were expected to develop 5,500 indicated HP. Although ordered three years ago, the progress in building the ship had been very slow, and on that account they would probably not be tried for three or four months. The power was expected to be developed with a piston speed of 780 feet per minute—a very considerable advance on the ordinary speed at which marine engines were worked. The boilers would be ten in number, larger than any of those which the author had used for his first-class boats, and would be divided into four stoke holes. It was hoped they would not require an air pressure of more than two or three inches of water. The cylinders were much larger in capacity for the power than those of torpedo boat engines, and in other respects the engines had not been reduced in weight to such an extent as the torpedo boat engines; but the saving in total weight was considerable. It was expected that the weight per indicated HP., instead of being 360 lbs., would only be 180 lbs. The saving in actual weight would be about 320 tons, or over 40 per cent of the weight of the compound marine engines with boilers of the ordinary kind, like those of the "Iris." He thought the system would be applicable to fleet passenger steamers making short passages, where a large coal consumption was a matter of little importance, considering the short time they were under way, and where they could easily be suppled with clean fresh water. He thought it would be worth while for the author to turn his attention in that direction. He did not think the paper admitted of much criticism. It was a record of well-merited success, and he was glad to have an opportunity of bearing his testimony to it.

METHODS AND STANDARDS OF PHOTOMETRY.

By HAROLD B. DIXON, M.A.

From the "Journal of the Society of Arts."

In the study of both heat and light we have to distinguish two quantities—intensity and total amount. In the measurement of heat, we are concerned sometimes with the intensity of heat in a body, or its temperature, at other times with the total amount of heat contained by the body. Similarly, in the measurement of light, we may have to determine one of two quantities—first, the intensity or intrinsic brightness of the light; secondly, the total amount of light emitted. The intrinsic brightness of the electric arc far exceeds that of any flame we can produce, but a gas flame with less intensity than the arc may be made to give a better illumination, by reason of the great magnitude of its radiating surface. In estimating the value of any source of light—such as an oil lamp, a gas flame, or a candle—what we are generally most concerned with is the total quantity of light it gives for a given consumption of fuel; in other words, we want to know, when we purchase an illuminant, how bright it will make our rooms, and how long it will last. The intrinsic brightness of the flame, apart from its illuminating power, is but a secondary consideration.

The sensations of radiant heat and light we experience when we stand in front of a coal fire, are produced by the impact of ethereal waves upon our nerves. The red-hot coal is composed of a number of molecules thrown into a state of intense vibration, by the chemical action going on between the air and the surface of the coal. These vibrations are communicated to the sea of ether pervading all space, and are transmitted to a distance as ethereal waves, just as the vibrations of a tuning-fork are communicated to the surrounding air, and are transmitted to a distance as aerial waves. As we stand in front of a fire, these ethereal waves beat upon us, and produce sensations of warmth and light. As the fire dies down, our sensations of warmth and light become feebler; but they do not disappear together. Long after we have ceased to be conscious of any light, we can feel radiant heat streaming from the ashes. On the other hand the full moon at night gives us the sensation of bright light, unaccompanied by any feeling of warmth. Yet the ethereal waves which produce these two sensations differ not in kind, but only in degree. Their undulatory nature is the same, their rate of motion is the same, but some are packed closer together than others, so that they differ in the rapidity with which they succeed one another, and strike upon our senses. Those which succeed one another at short intervals are called short waves, those which follow one another at longer intervals are called long waves.

The total radiant energy of a hot, luminous body can be accurately measured by completely surrounding it with a water jacket, and observing the increase in temperature which the water undergoes in a given time. The ethereal pulsations of every wave-length, radiating from the hot body, are absorbed by the surrounding water, whose molecules take up the vibrations, and are thus set swinging more briskly. This increase of molecular motion in the mass of water can be measured by a thermometer plunged in it. To raise one gramme of water in temperature through one degree, one unit of radiant energy is necessary. If therefore, we know the mass of the water, and we observe the number of degrees through which its temperature is raised in a given time, we have all the data required for calculating the total radiant energy of the hot body. But such an apparatus would not help us to determine the light emitted by a flame apart from the heat. Of the infinite number of waves of different lengths emitted by a white hot body, only a certain few are capable of exciting sensation in the human eye. When the crests of the waves of ether, beating on the eye, are more or less than a certain distance apart, we have no sensation of light. The longest waves that can excite vision give us the sensation of red, the shortest waves give us the sensation of violet. Waves of intermediate length give us the sensation of the other colors of the spectrum—yellow, green, and blue. When waves of all these lengths fall upon the eye in due proportion, we get the compound sensation we call white light. The eye is sensitive to ethereal pulsations only over a very small range. Waves of greater length than those which give us the sensation of red, and waves of less length than those which give us the sensation of violet, produce no sensation of light at all. Since the extreme violet waves are about half as long as the extreme red waves, the compass of our vision is very small compared with our audition, for it extends over a range corresponding with barely one octave.

Several attempts have been made to devise an instrument which should measure the heat produced in the absorption of only that particular set of ethereal waves which affects the eye. Leslie endeavored to measure the energy of the waves that excite vision, apart from the energy of the longer or shorter waves, by receiving the radiations from a luminous body on the bulbs of a differential thermometer, one of the bulbs being of transparent glass, and the other coated with lampblack. His idea was, that the long heat waves would be absorbed by both bulbs equally, but that the blackened bulb would absorb the light-producing waves as well, and so become hotter than the transparent bulb, which would allow them to pass through it unabsorbed. But, as Leslie himself proved, lampblack is a better absorber of heat waves than clear glass, so that the depression of the liquid in the tube connected with the blackened bulb is not to be wholly or even mainly attributed to the light absorbed.

Another and better attempt was made by Ritchie in 1825. The bulbs of his differential thermometer were composed of closed metallic vessels, with one thick glass plate side. Inside each vessel a piece of blackened paper was hung so as to intercept the rays which entered through the glass plate. The two vessels were placed side by side, these glass faces being turned in opposite directions, and one of the lights to be compared was moved nearer or farther away from the photometer, till the liquid in the bent tube connecting the vessels stood at the same height in both arms. Then, if only those rays which produce the sensation of light could pass through the glass plates, and if they were all converted by the blackened paper into heat, the instrument would give a correct measurement of the relative quantity of light rays falling on the two bulbs; but it would not necessarily inform us which of the two lights would appear the brighter to our eyes For unless it could be proved that our sensation of brightness varies directly with the quantity of luminous rays which fall upon the eye, and is independent of their wave-length or color, it might happen that two different sources of light might give out light rays which, converted into heat, would equally affect the two bulbs of the thermometer, and yet might differ in illuminating power, owing to our eyes being more sensitive to the rays of one, than to the rays of the other. But however this may be, it certainly is not the case that only those rays which excite vision can pass through glass and, therefore, Ritchie's instrument does not fulfill the first conditions of a photometer.

A similar objection applies to many other methods of determining indirectly the illuminating power of a source of light. There have been devised excellent means of measuring the amount of chemical or physical change produced by the action of light on certain substances, such as the darkening of silver salts, the combination of hydrogen with chlorine, the decomposition of hydrogen iodide, and the alteration in the electric conductivity of selenium; but such measurements are not determinations of illuminating power, but of certain portions of the total radiant energy of a luminous body, which include more or less completely the rays that excite our vision.

Since, therefore, the object aimed at in photometry is measurement of the effect produced on our eyes by any source of light, it is essential that the eye should be used to receivo the rays; and since it is impossible to remember at all accurately, even for a short time, the effect produced on our eyes by any source of light, it is also essential that we should have a constant standard of light, with which to compare other sources of light directly. The production of a standard of illuminating power, with which other illuminants can be compared, and the mode of such comparison, are the two problems in photometry to which I desire to draw your attention.

The official standard used in England at the present time is a sperm candle of six to the pound. This is the standard prescribed by the Metropolis Gas Act of 1860 for testing coal gas. Later acts, and the notification of the gas referees, contained detailed instructions as to the proper mode of employing candles; the candle must be cut in half, and lighted in the middle, so that, while one-half burns down to the thicker end, the other half burns down to the thinner end; the candles must have been burning fifteen minutes before the testing begins, so that they may have assumed their normal rate of burning; the candles must be weighed before and after each testing, and only those candles which burn more than 114 grains and less than 126 grains of sperm per hour are to be considered as standard candles, and a correction is to be made, when the consumption of sperm falls within these limits, on the assumption that the light emitted by the candles varies directly with the sperm consumed. But in spite of these precautions great discrepancies have been obtained by careful operators using sperm candles as a standard of light. On this occasion I can do no more than refer to the experiments of other chemists on sperm candles, among which the ingeniously devised observations of Messrs. Kirkham and Sugg, and the long series of determinations made by Mr. Vernon Harcourt occupy the most prominent place. In consequence of Mr. Harcourt's results, the Board of Trade, in 1879, appointed a committee to investigate the alleged untrustworthiness of the candle standard, and to examine and report upon three proposed standards—(1st) The sperm oil lamp of Messrs. Keates and Sugg; (2d) the gas burner of Mr. J. Methven; and (3d) the air gas flame of Mr. Vernon Harcourt. This committee was composed of Dr. A. W. Williamson, Dr. Odling, and Mr. George Livesey. I had the honor of being appointed Secretary to the committee, under whose direction I conducted the experiments I propose to recount briefly to the Society.

For our standard of light we employed coal-gas, stored specially for our use by Mr. Livesey, in a large gas-holder, at the South Metropolitan Gas Works. We found that the illuminating power of this coal gas remained remarkably constant for a lengthened period, and, therefore, was well adapted for our purpose. In the first place, candles of slightly different make, but coming under the Parliamentary definition of "six to the pound, and burning 120 grains per hour," were obtained from the London firms who manufacture sperm candles of the kind prescribed by the acts, and these candles were compared in an open and also in a closed photometer, with the stored coal gas. The results have been condensed in the following table, which gives the average obtained with each variety of sperm candle tested:

AVERAGE RESULTS.

Maker.	Threads in each strand.	Average consumption of sperm per hour	Illuminating power attributed to coal gas.	Relative illuminating power of candles.
Miller	21	112.6	18.42	94.3
"	18,18,19	110.1	17.37	100
"	21	115.8	19.18	90.6
Langton and Bicknell...	18	116.6	18.35	94.7
Ogleby	21,22,23	132.6	19.0	91.4

Taking the first two sets of figures, we see that the average illuminating power of one variety of Miller's sperm candles is more than 5 per cent greater than the illuminating power of a second variety of the same maker's candles, which only differs from the first in the number of threads in the strands of the wick. Looking at the individual testing made, we find that the illuminating power of the stored coal gas is given on one day as 16.0 candles, by one pair of candles, and as 18.5 by another pair; while on another day the illuminating power of the stored coal gas is given as 17.1 candles by one pair of candles, and as 19.5 by another.

In order further to test the variations of sperm candles, the committee had a photometer fitted to burn candles at both ends, which were made exactly similar in all respects. Each pair of candles was weighed before and after the experiment, and a corresponding correction was made in comparing their illuminating power for the sperm consumed. Each experiment consisted in taking ten observations at intervals of a minute. The following table contains the corrected results, the illuminating power of the less bright of the two pairs of candles tested being called 100 in every case:—

The letters A, B, &c., represent different varieties of candles, the figures following different candles.

Illuminating Power.		Illuminating Power.
A. 1 = 100	when	A. 2 = 101.6
A. 3 = 100	when	A. 2 = 101.6
A. 3 = 100	when	A. 2 = 101 5
A. 3 = 100	when	A. 4 = 102.5
A. 4 = 100	when	A. 5 = 101.3
A. 6 = 100	when	A. 5 = 105 6
A. 6 -- 100	when	A. 5 = 105.2
A. 6 = 100	when	B. 1 = 100 4
B. 1 = 100	when	B. 2 = 105.4
B. 3 = 100	when	B. 2 = 107.4
B. 3 = 100	when	B. 4 = 102.2
A. 7 = 100	when	B. 4 = 105.6
A. 7 = 100	when	A. 8 = 102.8
A. 8 = 100	when	C. 1 = 100.5
C. 1 = 100	when	C. 2 = 105.1
C. 2 = 100	when	B. 5 = 111.7
B. 5 = 100	when	B. 6 = 101.7
D. 1 = 100	when	B. 5 = 104.8
D. 1 = 100	when	D. 2 = 102.8

When the light of two pairs of sperm candles is compared directly in this way, the variations of intensity are strikingly apparent. The following are the actual readings taken every minute, in a test extending over 20 minutes, of the illuminating power of a pair of candles, the value of the other pair being assumed to be 16 in each case. The candles were from different packets, but of the same make. The highest reading is 19.2, and the lowest 16.2, a difference of more than 18 per cent, and within two minutes we find a variation of more than 12 per cent.

A. 16. Illuminating power.	A. 16. Consumption.	*v.* A. 15. Illuminating power.	A. 15. Consumption.
18.6	76 grs.	= 16	70.8
18.3			
18.7			
18.8			
18.9			
18.8			
19.2			
18.9			
18.9			
18.7			
18.2			
18.6			
18.4			
18.3			
17.9			
18.2			
17.3			
16.2			
17.5			
16.7			
18.25 mean.			

A. 15 = 100

$$\text{A. } 16 = 100 \times \frac{18.25 \times 70.8}{16 \times 76} = 106.3.$$

But the most convincing testimony against the candle standard is afforded by our third series of experiments, in which the stored coal gas was tested every day for a fortnight, with candles such as are now being supplied to the testing stations. The candles are sold in packets containing 6 lbs. or 36 candles. We found that candles out of the same packet were fairly uniform in illuminating power. But the average value of the candles from one packet differed very considerably from the average value of the candles from another packet. One packet, composed of fairly uniform candles, gave, as the average result of testings made with ten candles, the illuminating power of coal gas as 15.0, and another packet gave as the average result of testings made with ten candles, the illuminating power of the same gas as 17.2. The table (p. 274) contains the averages of at least ten candles from each packet.

In a parallel column are printed the results of testings made with Mr. Harcourt's air-gas flame of the illuminating power of the coal gas during the fortnight these experiments lasted.

Since the report of the committee was issued, Mr. Giroud has published experiments made with standard sperm candles, in which he tested them against each other, and against a standard gas flame. The results he has drawn up in a series of diagrams which show the position of

VALUE OF STORED COAL GAS AS GIVEN BY

Date.	Standard Candles. Packet.	Standard Candles.	Air gas flame
March 28	A.	16.19	
" 24	B.		15.9
" 25	B.	15.26	—
" 26	B.		—
" 27	C.		16.05
" 29	C.	15.21	—
" 30	C.		—
" 30	D.		—
" 31	D.	15.25	15 95
April 1	E.	15.02	15.9
" 2	F.	15.88	15.95
" 3	G.	16.87	16.2
" 5	H.	16.72	16.1
" 6	I.	16.24	16.2
" 7	K.	17.26	—
General Average....		15.99	16.02

the screen between the two candles, and between the candle and the gas flame, at each reading of the photometer. These diagrams reveal in a striking manner the rapid alteration from minute to minute in the intensity of light of a standard sperm candle.

Count Rumford, in experimenting with his shadow photometer, discarded the candle of his day in favor of an oil lamp, with a circular wick, as a standard of light. By means of this oil lamp he was able to prove experimentally that the illuminating power of a source of light varies in our atmosphere inversely as the square of the distance, and therefore, that the absorption of light by several feet of air is inappreciable.

An oil lamp, with a circular wick, burning purified colza oil at a certain rate, is used in France as the standard of light. Messrs. Keats and Sugg have introduced modifications into the French carcel lamp, and propose to employ a lamp burning pure sperm oil, with a two-inch flame as a standard. The lamp so contrived gives a brilliant and steady light, but unfortunately, the long wick sometimes becomes so brittle, when charred, that any adjustment of its length becomes impossible without danger of breaking it. The objections which apply to a candle as a standard, also apply, though in a less degree, to an oil lamp. The exact nature and form of a burning wick are incapable of accurate definition, and since the illuminating power is largely dependent on the nature of the channel which supplies the combustible to the flame, no standard seems likely to be trustworthy whose constancy depends on the uniformity of a wick.

Mr. Methven has devised a plan by which he proposes to measure the illuminating power of coal gas, by cutting off a small portion from the center of the flame of an argand burner, supplied with the same coal gas as that to be tested, and using that isolated portion as the standard of light. The argand he employs is the same "London Argand" used to burn the coal gas at the testing stations. In front of the lamp, between it and the screen, a brass plate is fixed, carrying a small thin silver plate, in which a slit one inch long and a quarter of an inch wide is cut. The plate prevents any other light, except that which passes directly through the slit, from reaching the photometer. The height of the flame is adjusted as nearly as possible to three inches, though small variations in the height of the flame do not affect the quantity of light which passes through the slit. We found that there was no appreciable difference when the flame was raised or lowered a quarter of an inch from the normal height. From this description, it will be evident that Mr. Methven's method is exceedingly simple, and little or no trouble is required to prepare the standard for use. The principle on which Mr. Methven founds his method may be thus stated: When different qualities of coal gas are perfectly burnt in an argand burner, at such rates as to yield a three-inch flame, the central portions of such flames will be equally bright, no matter what may be the quality of the coal gas supplied to the burner. A rich gas will give a flame which begins to be luminous nearer the orifice of the burner than the flame from a poor gas; but the screen, by cutting off this lower portion of the light, equalizes the two, as seen through the slit. To test the lamp, the committee conducted two series of experiments, using coal gas of different qualities to supply the Methven burner; the first series were made at the London Gas Works, the second, at the South Metropolitan Works.

The following Table gives the result of the first series:

Gas used at Standard Burner.	1. 21 candles.	2. 19 candles.	3. 16.5	4. 14.
Value assigned to stored common gas	17.11	16.90	17.08	17.15
" " "	17.08	16.89	16.92	16.93
" " "	—	16.92	16.86	16.95
" " "	—	—	16.92	16.99
" " "	—	—	—	17.04
Mean	17.1	16.9	16.9	17.0

In these experiments, the two intermediate qualities of gas were prepared by mixing the cannel gas of 21 candles with air. The excellent results obtained in this series were not repeated when the lamps were supplied with varying qualities of coal gas, obtained from the retorts at different periods of the distillation of ordinary coal. The rich gas used was that given off by ordinary coal during the first hour of the charge. The poor gas (13.6 candles) was made by mixing gas from the sixth hour of the charge with ordinary gas. The intermediate qualities were made by mixing the rich or the poor gas so collected with ordinary gas.

In the following Table are given the results obtained with Methven's burner, supplied with these different qualities of coal gas, and used to test the stored coal gas at the South Metropolitan Works:

1st Set. Dec. 1880.

Value in candles of the gas burnt at the Methven burner	13.6	14.3	14.9	15.5	15.8	16.4	17.6	19.0	19.6
Value in candles assigned to the stored coal gas	21.2	16.6	15.6	15.2	14.9	14.5	14.6	14.5	14.0

2d Set, with Fresh samples of Gas. Jan. 1881.

Value of the gas burnt at the Methven burner	14.4	15.5	16.2	17.8	18.5
Value assigned to stored coal gas	15.1	14.4	14.3	14.4	14.1

From these figures, it appears that variations in the composition of the gas may influence the light yielded by the Methven burner, and consequently some check on the Methven burner becomes necessary, in the absence of which grave errors might pass unnoticed in the estimation of a sample of coal gas. It is true that the Methven burner gives accurate results when burning the coal gas, generally sent out by the large London gas companies, and supplies a want felt by many gas managers—that of a rapid and easy method of testing their make of gas at any moment. But it is essential for a standard of light to be independent of any fluctuations in the quantities to be measured by it, and this quality the Methven burner does not possess in its present form. Mr. Methven is at present engaged in perfecting his burner, and, I believe, will shortly bring forward a lamp, better adjusted to give a constant light, with varying qualities of gas.

In Mr. Harcourt's air-gas flame, the supply of combustible matter to the flame can be adjusted with extreme accuracy. An illuminating gas, especially prepared for the purpose, is burnt from a large orifice in a brass burner, at such a rate as to produce a flame 2½ inches high. All the conditions of burning are capable of exact definition. The combustible matter is a certain portion of purified American petroleum, consisting mainly of the hydro-carbon pentane. The presence of higher and lower members of the paraffine series, which occur in American petroleum, such as hexane and tetrane, does not alter the illuminating power of the air gas prepared from pentane, when these bodies are present in such quantities that the specific gravity of the mixture does not vary beyond certain wide limits. In practice, therefore, Mr. Harcourt does not separate pure pentane from the purified petroleum, but separates a liquid having a specified gravity closely approximating to that of pure pentane, but containing, besides pentane, some tetrane and hexane. In this way, a fair proportion of standard petroleum is obtained from the crude gasoline imported into this country from New York. To try Mr. Harcourt's system, the committee first tested the stored coal gas at the South Metropolitan Works with samples of air gas prepared from different makes of standard petroleum, using alternately that of the highest and lowest specific gravity yielded by the process of separation. No difference could be detected in their illuminating power. Samples were next prepared and tested against the stored gas by different observers, with the same result. Then the apparatus being set up in duplicate, one air-gas flame was tested against a second, in the same manner as candles had been tried against candles. The results so obtained were concordant to a surprising degree of accuracy. I give two of the sets of readings taken, the illuminating power of one flame in each case being called 16, and each burner being supplied alternately from each holder.

1st Holder. Left-hand burner. Observations every minute.	2d Holder. Right-hand burner.	2d Holder. Left-hand burner. Observations every minute.	1st Holder. Right-hand burner.
(1.)		(2.)	
16.1	16	15.95	16
16.0		16.0	
16.05		16.05	
16.0		16.0	
15.95		16.05	
16.0		15.9	
16.0		15.95	
16.05		16.1	
15.95		16.0	
16.0		16.0	
Mean.16.06		Mean.16.00	

Two objections have been raised against Mr. Harcourt's system; first, that it requires such skill and care in the operator as to unfit it for general use, and, secondly, that the meter and governor employed are on so small a scale that they cannot be made to work efficiently. In answer to the first objection I should reply that skill and care are needed in working, but not such skill and care as cannot be found among the expert and conscientious chemists, who at present test the coal gas of the metropolis. On this point I can speak decisively. Mr. W. G. Wood, one of the official gas testers, after one day's instruction, was not only perfectly able to adjust the air-gas flame, and obtain exact readings of the value of the stored coal gas, but prepared a sample of the air gas from the standard petroleum, which gave exactly the same result as previously prepared samples. In answer to the second objection, that of the difficulty of constructing for the air-gas flame a sufficiently delicate governor and meter, an objection which has, I believe, been urged by those who make, and who therefore ought to understand them, I venture to reply that the makers underrate their own ability, and that the accurate working meter and governor before you, constructed by Messrs. Wright & Co., is sufficient evidence to completely dispose of this objection.

The method of comparing the illuminating power of two sources of light, by observing the distances at which the two lights must be placed from the screen, so that the portions illuminated by each shall be of equal brightness, was first adopted by Bouguer in 1729. Bouguer placed his lights behind a transparent screen, so arranged that one-half of it received the rays of one light only, and the other half the rays of the second light only, falling nearly perpendicularly on it. Exactly the same arrangement was afterwards adopted by Foucault in his photometer, who employed for his transparent screen two sheets of glass, pressing a uniform layer of starch between them. Rumford, in 1792, addressed to the Royal Society a description of a photometer, in which the two halves of a paper screen were severally illuminated by the rays of two lights falling at an angle of 60°. The observer sat facing the screen with the two lights behind him, one on each side. Two small wooden uprights served to protect from the rays of one light that half of the screen illuminated by the rays of the other. Each upright had attached to it a supplementary strip of wood, which, by turning the upright round, could be brought to project into the light, and so increase the width of the shadow thrown on the screen. By this arrangement, the shadows thrown by each upright could be made to accurately coincide, and the eye had less difficulty in judging when the two portions of the screen were equally bright, because they then presented one homogeneously illuminated surface. Mr. Vernon Harcourt, in his new photometer, which by his kindness I am able to exhibit for the first time this evening, has adopted a somewhat similar arrangement for his screen. The lights, as in Foucalt's photometer, are placed behind the screen, which is made of ordinary printing paper, No. 23, washed with water, and painted with a solution of spermaceti in petroleum. In front of the screen, and at a distance of about $\frac{3}{4}$-inch, is placed a brass diaphragm, having two similar vertical slits cut in it, side by side, at a distance apart equal to their own breadth. The two lights to be compared are similarly placed on each side of a line drawn perpendicular to the screen. Their rays fall at such an angle that the shadow thrown on the screen, owing to the solid piece between the two slits stopping the rays of one light, is exactly illuminated by the rays of the other light passing through one of the two slits.

By adjusting the distance of the brass diaphragm from the screen, it is easy to make the shadows accurately coincide, so that when the central portion is as bright as the two outside portions, the screen presents one homogeneously illuminated surface. With this photometer, I have recently made a few experiments in Mr. Harcourt's laboratory; and I have taken from his note book the following numbers, which represent independent tests of the illuminating power of a small sample of coal gas stored in the laboratory:

Illuminating power of stored coal gas.	Observer.	Date.
16.5....	H. B. Dixon.	Dec. 8th, 1881.
16.8....	A. V. Harcourt.	
16.5 ...	H. B. Dixon.	
16.4...	A. V. Harcourt.	
16.5....	H. B. Dixon.	
Mean 16.4		

Illuminating power of stored coal gas.	Observer.	Date.
16.5....	H. B. Dixon.	Dec. 9th, 1881.
16.5....	"	
16.5....	"	
16.5 ...	S. E. Miller.	
16.5....	"	
16.5....	"	
Mean 16.5		

In this photometer, the two lights and the disc are kept stationary, and the equality of the shadows is obtained by adjusting the coal gas supply. The photometer tells us at what rate we must burn the gas in order to obtain a flame of 16-candle power.

Bunsen was the first to employ a disc, having a portion of it made more translucent than the rest, and placed between the two lights to be compared. When such a disc is illuminated more strongly in front than behind, the translucent spot seen from the front, appears dark on the bright ground, while an observer behind the disc sees the translucent spot bright on the dark ground. When the disc is equally illuminated on both sides, the spot appears neither brighter nor darker than the rest of the disc. In the official measurement of the illuminating power of London, coal gas, the Bunsen disc is employed, and either the lights are kept stationary, and the disc moved, or the gas flame and disc are kept stationary, and the candles are moved until equal illumination is obtained. The distance of the two lights from the disc are then read off, and the squares of those distances give the relative illuminating power of the lights.

Since the light of a sperm candle is redder than the light of a common gas flame, it is impossible to adjust the photometer so that the two sides of the Bunsen disc appear alike. In using the Bunsen and the star disc I have generally adjusted the distances of the lights so that the circle or star appeared equally distinct on both sides, the pattern enabling one to form an idea of distinctness apart from color. But though extremely close readings may thus be obtained with the same disc, a change of disc, or a mere reversal of the same one, occasionally introduces a considerable variation in the apparent illuminating power of the coal gas. On the whole, therefore, I consider the shadow photometer the fairer instrument.

Another method of determining the equality of two illuminated surfaces was first proposed by Arago. When a beam of light passes through a crystal of Iceland spar it is divided into two rays, polarized at right angles one to the other, called the ordinary and the extraordinary rays. A nicol prism is formed of two pieces of Iceland spar, joined together by Canada balsam in such a way that only one of the two rays, into which the beam is divided, passes through it. Now, if the light from two equally illuminated surfaces is allowed to pass through a crystal of Iceland spar, we see four images of the two surfaces, because each beam of light is divided by the crystal. If the size and position of the illuminated surfaces are so arranged that the extraordinary image of one just coincides with the ordinary image of the other, we see three images on looking through the crystal, but the double image is, of course, brighter than the other two. The brighter image is really composed of two images, superposed one on the other, and if its two components are of equal intensity, the resulting light is ordinary unpolarized light. The other two images, composed of polarized light, will exhibit colors when examined by a thin plate of selenite, or by a plate of quartz, cut at right angles to its axis, combined with a suitable analyzer. The central image will also exhibit colors, when thus examined, if its two components are not of equal intensity; for in that case there will be a surplus of one kind of plane-polarized light over and above that required to neutralize the other kind. The lights are therefore adjusted, until an observer, looking through the instrument sees the central image white, while the two side images are colored with complementary colors. The two lights are then of equal intensity. In this form of photometer, it is essential that the two lights should be of the same color exactly, otherwise the color changes of the polarized light are valuless as indications of intensity. This objection to the instrument has prevented its adoption for testing the illuminating power of gas by comparison with a standard candle.

Several methods have lately been devised for comparing, by means of the polariscope, the intensity of corresponding portions of the spectra of two lights of different color. Such methods give an accurate measure of the relative intensity of individual colors present in both lights, but they do not compare the total intensities. Again, by superposing such portions of one spectrum as yield a tint similar to the tint of a portion or portions of the second spectrum chosen for comparison, a nearer approach to an accurate measurement of the total intensity may be reached; but since only some fraction and not the whole spectrum is taken, an approximation to the truth is all that can be obtained. Instead of comparing portions of the spectra of two sources of light, it is more simple to look at them through colored glasses; in both cases only some fraction of the light is measured, and it can make little difference in the result, whether certain colors of the spectrum are cut off from the photometer by a diaphragm, or are absorbed by a colored glass. In a small portable photometer, designed by Professors Ayrton and Perry to compare lights of very different intensity and color, such as electric lights with a sperm candle, the brighter light, before falling on the screen, is diminished by passing through a concave lens, whose distance from the screen can be adjusted till the intensity of the more or less diverging ray is equal to that from the candle. The two shadows are compared first through ruby-red glass, and secondly through signal-green glass. Since the electric arc is comparatively richer in shorter waves than the candle flame, the shadow comparison is more in favor of the electric arc with the green glass than with the red. Messrs. Ayrton and Perry do not give the mean result as the relative illuminating power of the arc and candle, but admitting the impossibility of truly comparing two different colors by eye, give both results as indicating the relative intensities of the two sources of light for the particular light waves severally transmitted by the two colored glasses.

The second 80-ton gun for the turret has been successfully landed at the Admiralty Pier, Dover.

TRESTLE BRIDGES AND MODES FOR MAINTAINING THEM.

By J. H. CURTIS, C. E.

From the Papers of the Pi Eta Society.

In the construction of trestle bridges as a means of quickly repairing a break in a railroad, due to the burning or failure of a permanent structure, the best practical skill and ingenuity of our pro fession are in demand. Little information can be obtained from books on this subject, and only that far-seeing judgment and quick perception which constitute the shrewd practical man are of any value in such an emergency. The object is to do all that is required, often having little with which to do it. To remove a mass of earth in case of a wreck, to plant mud sills and to carry forward the carpenter's work with such rapidity that, by the time the ground is cleared, an entire line of trestles is ready for erection, is a requirement .difficult to comply with. Little care can be given to the preparation of the timber. A builder's level and a tape measure in the hands of the one in charge, with cross-cut saws, squares and plumb lines, comprise the necessary instruments and tools for the work. To begin the work, project an approximate center line of the track over the break, and on this drive pegs a panel distance apart to locate the base timbers, or "mud sills," as they are usually called. If the structure is to be more than one story high, assume the height of the first story, giving attention to the lengths of the timbers so that they will work economically, and not be wasted in cutting. Take the greatest pains in planting mud sills to make them firm and level, otherwise there will be no end to trouble, both in construction and subsequent settling; at the same time be regardless of their relative height, but adjust that matter in the lengths of the verticals. By establishing a straight edge on the embankment at one end of the track parallel to the track grade, and at the height of the first story, an observer stationed there can range along the entire work, and separately, for each bent designate the heights of the upper cap surface above the mud sills by means of a level rod held thereon, or what is better, a straight stick lifted vertically to line of sight and the proper lengths cut off to serve as a measure. Each vertical will have its length less the thickness of the cap stick and surface sill for its respective bent.

Thus the work is distributed over the entire break. Each bent should have from two to eight verticals, the number depending upon the width and height of the structure. Care should be taken to have all the timbers squarely sawn and the cap sticks, perhaps the surface sills also, securely fastened to them before the bent is raised, as it can then be best "squared" and the bases "scribed in." Commence erecting the bents as soon as any two consecutive ones are framed, securing a connection with the embankment as soon as possible, that the stringers may be run out and a portion of the track placed in working order, or another story added, as the case may be, and all hands be constantly employed. With due care in framing, all the cap sticks will have nearly the same height; however, any slight differences existing produce no serious inconvenience, as the stringers may be "sized on," that is, worked down at the bents where the cap sticks are most elevated until they rise evenly on each. Should a cap stick be exceptionally low, a piece of timber of the required thickness may be spiked on to it and the stringer notched or worked into this. Wedges should not be used for this purpose, as they are liable to be jarred out. Having done all this, it will be found that the stringers are not quite parallel to the road grade, but have small inequalities; this is obviated by working the sleepers to the required thickness. If the trestle is to be only for temporary use, an additional width should be given it, and the cap sticks have at least a length of twenty feet for a road of single track. On these the lower chords of the bridge, which is to replace the temporary structure, may be placed the trusses assembled, and in order not to impede the traffic while the cross girders and braces are being placed underneath the track, it may be bodily lifted and blocked up, to be lowered again when everything is in readiness, and the bridge swung.

Care must be taken to brace every part of a trestle. A system of horizontal braces between caps is desirable, as it serves to take up lateral oscillations, which tend to throw the track out of line—a thing to be closely guarded against. This difficulty is increased if the foundations are bad, and no subsequent work will entirely remedy it, the only alternative being to line up the track. Therefore, look well to the foundations. Any ordinary soil is sufficient if well drained and the sills placed below frost. If partially dry quicksand is encountered, an excavation can be made and the bottom covered with a foot of gravel. I have obtained good results on oozy and mucky ground by placing a few inches of sand in the excavations. The object secured was the prevention of water being forced out during the passage of a train, to be returned by the pressure of the atmosphere. As regards trestles in flowing water, affairs become complicated. Any obstruction causes a disturbance of the water, and if the bottom is of a yielding character, a scouring action takes place. However, trestles may be protected against this, even in wide and turbulent rivers by taking the proper precautions. I will first note the difficulties, then give a remedy. I cannot enter into all the details of the subject, but will give some facts which I have observed in regard to the drifting of sand, due to the mechanical action of flowing water, a description of which was made in a report to the U. S. Engineer Department some time during last September. The water in flowing rivers does not move forward in horizontal layers, as many writers have said, but is continually revolving in vertical curves, impinging against the bottom, then coming to the surface loaded with sand and again descending; in fact, simply rolling, propelled by gravity and revolved by reason of contact with the bottom. Its mean velocity is, perhaps, measured at mid-depth or a little below.

Now, if the mechanical action of the flowing water on the bottom is uniform for any considerable portion of the river, there will be no scour nor fill, as the material carried forward will be replaced by other material from above, the quantity depending, in a great measure, on the velocity and volume of the river, and in its movement, being governed by the same process as the flowing water, viz., gravity and resistance due to friction on the bottom, giving it a rolling motion. Just in what manner the water acts on the bottom of the river is unknown, but some of its results have been determined. During a series of discharge and sediment observations made on the Arkansas River, at Pine Bluff, extending over a period of six months of last year, great care was given to a study of this subject, and the rolling motion of the bottom to a variable depth was discovered; this depth was never less than five inches at extreme low water, and in high water was greatly increased. It was found that the movement partook of the form of sand waves, sloping gradually upward and abruptly downward in the direction of the stream.

These waves traveling at an average distance of 22½ feet apart during low water, represent the successive forms of rolling sand. The long inclines are scoured off, drifted over the crests and deposited, there to remain until the entire wave passes over, to be again picked up and deposited as before. By careful observations, the contents of this moving volume were measured from day to day; it was found that in very low water and in a mean current the sand waves had a height of only ten inches and no perceptible movement, but with a slight rise they would start forward and the volume discharged seemed to have a ratio to the discharge of water. During thirty-five days at Pine Bluff, from June 10 to July 15, 1879, the discharge of sand and of water had a ratio of one cubic foot of the former, to 440,000 cubic feet of the latter, and these observations taken at the time of very low water, showed this volume to be smaller than that carried entirely in suspension, both in bulk and weight. I have no doubt the ratio would be enormously increased in time of flood, but unfortunately there was no high water during the time of the observations, to give opportunity for experiments, but I know that waves five or six feet in height were incidentally found at a stage of 18 feet above low water, where the maximum high water stage was 30 feet.

I have thus called your attention to bottom drift in alluvial rivers, in so far as it relates to our subject, but the investigations which have been made to determine the above facts, would be unnecessary.

From this it can be seen that low water is the only condition in which the bottom of an alluvial river is sufficiently quiet to permit of a trestle being placed in it, but this once done, there remains only to protect it from the scouring action of the water, occasioned by even the smallest rise.

First, the trestles should be made of piles well driven down, to insure stability (although in a navigable river this might ruin navigation), and located in a wide shallow crossing, immediately after a sudden fall of the river, before the high water deposit has been scoured out.

Mattressing should accompany the trestling, so that when the latter is finished, the bottom of the river will have a brush carpet from shore to shore, extending above and below the trestles at least fifty feet.

The mattresses should not be over a foot thick, the size varying according to the depth and velocity of the water, and the circumstances under which the work is done. Usually, a large mattress would be preferable to a smaller one, as the cost per foot is less, and under favorable circumstances it might possibly be woven continuously from shore to shore, the whole work consisting of one piece, in which case the amount of small stones necessary to hold the work in place until it should fill with silt would be very small.

RAILROAD ECONOMICS, OR NOTES AND OBSERVATIONS FROM THE OHIO STATE RAILWAY INSPECTION SERVICE.

By S. W. ROBINSON, C.E., Prof. Mech. Eng. State University, Columbus, Ohio; Member of the Board of Inspectors under the Hon. H. Sabine, Commissioner of Railroads and Telegraphs.

Trunk and other Lines.—In Ohio, as well as in at least two other States, there appear to be two classes of railroads,—first, the great trunk lines connecting the West with the East, and, second, those having largely or altogether local interests. The former are most likely to run east and westward, while the latter run mostly north and southward. Strong. companies control the former, while the latter often fail to pay well enough to keep up repairs. In many instances a weak company sells its interests to a stronger, when the former causes a general need of repairs. The strong company or trunk line then puts the road into good running condition, sometimes to form part of a through line, sometimes a branch, and sometimes to form a tributary to it. In this way a road of secondary importance may be kept up to good running condition, while otherwise it would go down.

Whatever may be said against consolidation of railroads, it appears to be a fact that roads owned by strong and wealthy companies are in far better condition than otherwise. Indeed the generally good condition of the great trunk lines and of their branches is a credit to those companies. If these roads are backward in some things, such as introducing the best systems of "signaling," "blocking," and of "interlocking apparatus," they are certainly up in other matters, such as steel rails, iron bridges, &c.

Safety.—A little attention to railroading will suffice to show that safety in railroad travel is the price of incessant vigilance. That a stretch of three hundred miles, extending across a state is, every foot of it, perfectly safe to-day, is not proof positive that it will be so tomorrow, though the broken rail or washed culvert is the subject of constant search.

Protection of Railroad Structures.—The life of railroad plant is not great. New roads, with iron rails and wooden structures, will need renewals for the most part within ten years. Rails endure according to traffic, and for light traffic will run ten years. Ties will rot out in from five to eight years. Culverts, cattle guards, &c., about the same. Good wooden bridges, when new, will be dangerous in ten years unless covered. If covered at all it should be done within two years after building, otherwise the timber becomes affected with dry rot at the the heart. This decay might perhaps better be called *blind rot*, because it is hidden. A wooden bridge, nicely covered and painted, may *appear* to be in the best of condition, but really be in the very worst. Joints in the lower chord of such bridges are seen to be pulling out by the locks splitting off. In such cases, when the timbers are sounded with a boring bit the latter \ ill find sound wood for two or three inches, when suddenly the bit may take a jump of four or six inches through a dry rot hole. Such well-covered and well-appearing bridges are found not to have been covered under about three years after building. Equally good uncovered bridges, even better, ten years old, have been found than those of equal age, well covered, in which the covering was delayed three years. It appears that after three years of exposure to open weather, a bridge is doomed to a life of only about ten years covered or uncovered.

But by prompt covering of wooden bridges the life is more than doubled, from which it appears that the practice of covering such bridges is highly economical.

It is sometimes the practice to cover simply the trusses, and it is necessary in "half Howe" or "pony trusses of wood. This leaves the floor system exposed, and any sap wood about the floor-beams or the stringers is soon eaten away with decay. Sap is of but little worth after three years' exposure, even when free. But heart wood is often perfectly sound at ten or fifteen years. Sap wood is so comparatively worthless that some engineers specify that not over eight per cent. of section of timbers shall be sap. It is an excellent precaution to thus limit the sap wood, because it is practically of no value. In existing bridges sap wood rot has reduced the section of chords, as estimated, from ten to twenty per cent., the remainder being sound. Uncovered flooring should, therefore, be watched, and when the beams are found weak, as by observed excessive deflection, new beams should be added.

Painting is an excellent practice, and its power for prolonging the life of wood is not confined to free or external surfaces, but internal as well,—that is, to illustrate, lower chords have been examined where the wooden "clamps and keys" were laid in white lead, or sometimes in red lead, and such are sound and strong to a greater age than unpainted.

A close joint in wood, where exposed, is far worse than open joint of small space sufficient for air to pass. From this fact it appears that wood contacts have been avoided by using iron "clamps and keys" in lower chords. Some engineers make iron clamps or blocks with a space for ventilating between wood and iron, the bearings being quite narrow. These have given good results, and point to the value of ventilation.

As to ventilation in general, all coverings should leave the main bridge timbers free for air to circulate about them. For instance, the boarding along the sides of trusses should be firred out by girt strips being nailed to the truss along the braces above the lower chord and below the upper chord, and not on the chords themselves. Then, when the boarding is nailed upon these girts, it stands out free, so that air can freely go all about the chords.

In some instances chords have been found covered with tin, the same being fitted about the braces and nailed to the chords, so as to appear like giving protection to the chords beneath. But this is believed to be worse than no covering whatever from the simple facts that, first, water will work in at the numerous joints, and, second, be held there by the tin covering. If the tin could be carried away from the wood by a 2′ space, the latter being allowed for ventilation, it will serve a good purpose when it is made tight. These conditions are readily met in "combination" bridges, that is, in such as have wood upper chord braces and end posts, but with iron ties and lower chords. The upper chords are readily covered with tin, because nothing protrudes above to prevent. The braces, or vertical pieces generally, do not need covering, as it is found that the wet so rapidly escapes as to leave the braces soon dry.

Special pains should be taken to keep wet out of close places in wood. For instance, in deck bridges (Howes), water is apt to leak through the roof, as it is difficult to lay a roof among the ties, floor beams, string, &c., in the floor system and get it tight. In such cases the sway braces are apt to carry the water which falls upon them down upon the lower chord. This has been avoided very neatly, cheaply, and efficiently on the Lake Shore and Michigan Southern Railway, by making a saw cut across the top and edges of the sway braces, and driving in a collar of sheet iron or tin, which extends down like spurs below, and thus heading off any water which may find its way through the floor or roof above, and alight upon the sway brace to come trickling down upon the lower chord.

But though tin may be suitable to cover upper chords as above explained with reasonable durability, yet as a main roof covering over the tops of Howe bridges it appears to be utterly worthless, for the reason that the sulphurous fumes of the smoke from the locomotive soon eats the tin roof through like a big pepper-box lid. Indeed this action upon iron has been observed upon heavier masses of iron than tin; the truss rods even having been observed in badly rusted or pitted condition, with a weakening of probably five to ten per cent. The latter has been observed to be most serious in low lands, such as would be frequented by fogs. The moisture of the latter deposits upon the rods and absorbs the acids of the smoke. The iron is then etched more or less seriously. Rods for such localities should be made with some excess of section to provide for the corrosion.

Wooden Bridges.—The prevailing wooden bridge is the Howe truss. It consists, as generally put up, of an upper and lower chord, connected by vertical tie-rods running through with nuts at both ends; the latter dividing the span into panels containing braces and counter braces. The chords usually are made of four sticks, side by side, with blocks or "keys" notched in, but leaving a space between all the sticks. Chord bolts run through from side to side of chord to draw all together. In short chords the sticks run from end to end. But for lengths greater than about forty feet, pieces are put in so as to break joints. In upper chords these simply abut against each other, but in lower chord clamps are used to make tension splices. These clamps are generally of oak wood, and preferred by some builders of the first and by some of the second form in Fig. 1. Sometimes only one is used to a

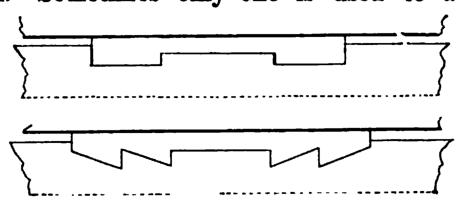


Figure I.

splice, as shown, but more often two, one on each side of pieces joined. A chord bolt goes through near each end of a clamp. The earliest point of failure in a wooden bridge is at the locks of these clamps, either on the clamp itself or on the interlocking hooks of the chord.

Two of these splices are never found opposite in a chord, but break joints, so as to allow one joint to each panel. In this way the so-called keys help to form the splice. There are always two main braces and one counter brace between in each panel. The former always incline toward the middle span point. In moderate spans there are always two tie-rods at each inter-panel point, but in long spans there may be three at the ends of truss. The largest of these rods are 2″ in diameter; almost always threaded without enlargement of ends. These ties draw against straps on the outside of the chords, running from $1'' \times 5''$ down to $\frac{1}{2}'' \times 3''$ in section, and long enough to extend the width of the chord. The braces almost always set square against iron angle blocks. The best of these blocks have flanges to prevent the braces from falling out of place. These blocks are often found broken, but the breakage is evidently due to carelessness in drawing up the tie rods too tight upon the braces, because on some roads these breaks are very numerous, while on others the same make of blocks are never found broken. Road masters say they find difficulty in getting men to draw their ties up properly upon the braces.

The depths of these trusses vary. Short spans, or "pony" trusses, sometimes also called half trusses, run from about eight to twelve feet height. Full trusses for longer spans are usually about twenty feet. The smaller trusses have about three or four floor beams per panel, while the larger have five. They always rest upon the chords.

When wooden bridges show signs of failure the speed of trains is often reduced till a remedy is applied, either in strengthening the bridge or by renewing it. Two ways of strengthening a lame bridge are in use. One consists of springing a wooden arch from the abutment, usually from iron skewbacks, placed about six feet down, and rising at mid-span nearly to the tops of the trusses. Each case requires four arched ribs, one on each side of each truss. From the arches the trusses are suspended by rods. But this method is too expensive for an old bridge; it is more common for a light bridge otherwise good. The second way to doctor the bridge, and which is very common for old bridges, is to put a trestle bent under at the third or quarter span. A pile bent is sometimes used instead of a trestle bent. The objection to placing the bent at the middle is the fact that the counter braces near the middle in that case become main braces. Some less considerable road masters place the doctor at the middle, however. But as the carrying power of a truss varies inversely as the square of the span, other things being equal, it appears that the strength of a bridge is nearly doubled by placing a support at the one-quarter point. Such trestle bents are carefully watched to guard against washing out by the stream. In high water such a trestle bent is a treacherous affair, a pile bent being far preferable.

The lateral bracing in bridges is almost always about the same, viz., about 6×6 braces and $1\frac{1}{8}''$ tie rods, and the same from end to end of bridge. These are usually in the plane of the lower chords and also upper. No difference is made in the strength of the lateral bracing, as far as observed, for straight or curved track, though it is certain that the centrifugal force of a train running on the curved track over a bridge will give cause for lateral thrusts, which are considerably greater than for straight track. One element of compensation, however, exists in the fact that bridges under curved tracks are usually wider, so as to allow equal clearance room, and this gives wider lateral trussing. Trusses are not found inclined on account of curves on the bridge.

Through bridges of wood have no "sway" bracing. The chords of the trusses are from 24″ to 30″ in breadth, and the floor beams extend entirely over to the outsides. This keeps the lower chord in position. The braces cover about the whole width of the chords, so that the trusses are quite stable in erect position.

Deck bridges always have sway bracing, but in some cases much stronger than others. Where several spans of wood bridges are contiguous, in some cases both or all are made continuous from span to span. In other cases only one chord will be continuous. Diagrams taken, as hereafter explained, have shown that in continuous two-span bridges an appreciable rise of the second span occurs when the train gets fairly on the first.

Iron Bridges.—The prevailing form of iron bridges is the Pratt truss for long spans, and for short the plate girder. The change from one form to the other occurs usually at lengths between sixty and a hundred feet. These statements apply more definitely to recent practice than former. The older iron bridges are very promiscuous, both as regards form and manner of putting together. Some of the first iron bridges in the State were Howe trusses, one of which went down in the Ashtabula disaster. But in place of the latter we now find what is probably the strongest iron Pratt truss in the State, so that people need not now go around Ashtabula to avoid a second catastrophe.

The parts of truss bridges were formerly united in various ways, sometimes by bolts, notches and locks, and often by riveting in place. But at present the method by pins and eyes prevails, especially for the longer trusses. In upper chords, however, though the tie rods are usually attached by pins, yet for increasing the rigidity they are made continuous by riveting on splice pieces extending past the pin holes. The forms of parts of bridges, as well as the methods of joining, are almost as though stereotyped. Thus the "eye-bar" is an article of manufacture, and is used in all parts of bridges except upper chords and struts or columns.

Upper chords and end posts are most frequently made of two channel bars, twelve to eighteen inches apart, with webs vertical. They are joined on top by a longitudinal plate extending the whole length and riveted to the flanges, while the bottom side is latticed or "laced." "Webb" members serving as struts are most frequently composed of two channel bars at a distance apart, and connected by diagonal lattice slats riveted on. Sometimes, however, the two channel bars are riveted by their webs to the flanges of an I-beam. Formerly Phœnix, Keystone, Box and other columns, nearly or quite closed, were much in use, but they appear to have given place almost entirely to such open columns as above mentioned, simply from the necessity experience has developed of painting every inch of surface in iron bridges.

Most engineers require forms such that a paint brush can touch every part, either inside or out. The advantage of this is seen from the fact above mentioned of the rusting of truss rods and of tin roofs from moisture and smoke. The statement also, which has come to my notice, that tons of rust have been removed from tubular bridges, is in point.

Floor-beams, made by riveting four angle bars upon the edge of a plate—two upon each edge at opposite sides—are the most common. The section approaches that of the eye-beam. Plates are often riveted on top and bottom, part of the length, to increase the strength at the middle part where the moment of strain is greatest. These beams are most frequently suspended from the pins of the trusses by inverted "∩" bolts. But when there is scant room below a bridge for water way or otherwise, they are in some cases riveted to the vertical struts.

The stringers are most frequently of rolled I-beams.

The lateral stiffening is much better attended to in iron bridges than in wooden ones. The lateral ties not only vary in size, from end to middle, but differ in size according to span, width, &c. There is generally a lateral system at both the bottom and top chords.

Plate girders are usually formed by riveting angle bars to the sides of the webs, top and bottom, then across these a flange. The latter is increased by additional "lifts" laid on the middle portion. These plate girders are usually of uniform depth, though some have been met in which the upper flange or chord was arched so as to nearly join the lower chord at the ends. Vertical stays of angle bars are riveted to the web throughout these girders, but nearest together at the ends, their object being to prevent the buckling of the webs. Most usually the two girders of a bridge are joined by riveting to the floor beams, so that all forms a connected system. An angle plate then is set between the floor beams and girders, to prevent the latter from swaying or careening.

But on some roads many of the plate girders have wooden floor beams; the latter sometimes resting directly upon the lower flanges, and sometimes on angle bars riveted to the girders. A neat and serviceable small bridge, where there is sufficient water-way, consists of plate girders, about ten feet apart, with lateral and sway bracings, and upon which are mounted the wooden floor beams. This plan is carried down to I-beam girders of ten feet span or less.

In a few instances weak iron bridges have been strengthened by springing iron arched ribs from the abutments, composed of channel iron, and securing the same to the trusses of a suitable number of points.

At the present day many good iron bridges are found to be too weak. This is due not to any engineering defect, but to the growth in weight of freight loads and rolling stock. We now find sixty-ton locomotives where formerly there were forty; and twenty-ton loads per car where there were ten. Hence bridges designed to a strain of 10,000 pounds per square inch of iron section, as due to the former loads, must now stand 15,000, or perhaps more. This is unfortunate, since an iron bridge is so difficult to strengthen in a satisfactory manner, and so difficult for the road men to get renewed.

Expansion and contraction of iron bridges is provided for in supporting one end on rollers. In short spans, however, rollers are dispensed with, and the bearing plates slide. Often the observed expansion reported by bridge attendants does not account for the whole variation of length, even where rollers are in use. It is believed by some that the rolling resistance under so much weight is so great as to spring the piers where piers are tall. Thus it appears that strains, due to constrained expansion, may be too great upon chords to be ignored in calculating total strains.

Strains under Maximum Loads.—In proportioning the parts of bridges for resisting their strains, a great variety of detail exists in the present practice. We find no "live" bridge engineer of to-day adopting a fixed maximum load per foot for all spans, even for the same road and the same trains; neither do we find the same fractional part of the ultimate or elastic resistance of the iron adopted for the allowable strain for all parts of any one bridge. The factor of safety is "a thing that was" to such an engineer.

In the first place the quality of the iron is allowed to differ for different parts of bridges. Tension members are never made of anything but "double-refined" iron, that is, iron that has been double rolled. This consists of taking "muck-bars" (the result of first rolling from puddle blooms), cutting and piling them, reheating to a welding heat, rolling into bars, then cutting, piling, and reheating again, when they are rolled to the needed sizes. Compression pieces are single refined, in which the last piling and rolling above described is omitted. Channel bars of columns and upper chords are thus treated.

A fair quality of double refined iron in bars should have a tensile strength of 50,000 pounds per square inch; an elastic limit of 26,000 to 30,000 pounds per square inch; should stretch fifteen per cent. in eight inches; bend 180° around a cylinder of diameter equal its thickness without fracture; and when knicked and broken should show a fibrous structure. Such iron in the regular truss tension members is usually allowed to be strained to 10,000 pounds per square inch for the maximum load. In some cases floor beams are allowed 8,000 pounds only, because they are strained nearly to the maximum allowed for each passage of load. This is true of floor beams, because the greatest load occurs when under the drivers of the locomotive. In the main truss, however, the maximum strains are only reached when the whole train is up to the maximum, a condition which does not happen with every train. The ∩-shaped hangers for floor beams are usually allowed only 5,000 to 7,000 pounds. Struts and upper chords are computed as columns, and on a supposed basis of about 8,000* pounds square inch. This low value is probably partly due to the fact of single rolling for channel iron.

Assumed Maximum Load.—In calculating the maximum strains there are two ways of treating the question of the maximum load.

1st. By adopting the greatest actual train weights, such as two of the heaviest locomotives, followed by a train of the heaviest loaded freight cars; then computing the strains as static effects to which results are added, for "dynamic effect,"

For spans of about 30 feet	25	per cent.
" " " 50 "	15	"
" " " 75 "	10	"
" " " 100 and over	... 0	"

2d. By assuming fictitious train weights which are uniform per foot for the span, but which are much the greatest for short spans. Thus, for some roads on this plan, the assumed load for calculating strains is:

For spans of 10 feet	.....6000 lbs.	per foot.
" " 40 "	4000	" "
" " 150 "	3000	" "
" " 500 "	2500	" "

This diminishing scale is to be accounted for as providing, first, for impact; the latter being greatest for short spans, because so much more quickly passed by the forward end of a train, and causing an application of load which is so sudden as to be of the nature of a blow; and, second, because short spans have the locomotive itself for the maximum load, while longer spans can only be covered by adding to the one or two locomotives, some portion of the train.

Crystallization of Iron in Bridges.—As regards the deterioration of iron in use by crystallizing, there are differences of opinion and two few facts. One man will present evidence of crystallization, while another will produce equally good evidence against it. It appears that data are too uncertain. When rods taken from a bridge are found to be crystalline, it is not known whether they were not so when put in. But this matter will be

* By a rational formula for columns, published by the writer since this paper was presented to the Society, it is shown that this value should be but a little over 6000 pounds. (See VAN NOSTRAND'S ENGINEERING MAGAZINE, for June, 1882.)

settled in due time, because positive data now exist as to the condition of iron in existing bridges. When the future engineer shall examine the parts of these bridges, and compare notes with the former records, we shall know how about crystallization.

Steel Bridges.—We are now at the verge of a steel bridge era, several important steel bridges being already built, and in process of construction. The most important mechanical difficulty in this direction is already overcome in the existence of machinery, for the manufacture of solid steel eye bars. Steel is in every way better fitted for bridges than iron. It is less subject to deterioration, becoming more uniform in results of manufacture, has an ultimate strength of nearly double that of iron, and an elastic limit from two to three times as high. Considering the strength, it is but little, if any, more costly. This step from iron to steel is but the natural course from cast-iron up, which latter material is now entirely abandoned as a material for bridges, except for unimportant members, such as wall plates, packing pieces, etc.

Sway Bracing.—In both wood and iron bridges "sway" bracing is universally employed in deck bridges. But such bracing is held in doubt by some, except at the ends of the bridge, where it should be especially strong. The reason given for this belief is that where one truss receives a greater strain than the other from any such cause as wind against the train, train at one side, as in double-track bridges, curved track, etc., the truss should be allowed to remain in a plane. But the sway braces preserve the cross section, so that if one truss deflects more than the other, each truss must careen to one side to some certain corresponding extent at the mid-span, but not at the ends, because here the solid abutments prevent. This forces the chords laterally out of a straight line, causing horizontal transverse strains upon them. The eye bars on one side of the lower chord would, under these circumstances, be strained more than those on the other side, an inequality which would disappear in the absence of sway bracing. Not only would the main trusses be affected, but the lateral bracing at top and bottom would be strained unduly, and probably higher than provided for in the oversight of this matter. The old Ashtabula bridge was an iron deck, and who can say to what extent the sway bracing were responsible in the failure of it?

Though the one consideration of greater flexibility of cross section seems to favor the omission of sway braces, in that we thus obtain freedom from stresses in one system of bracing as due those in another system, yet it is probable that the yielding cross section will allow the train, while under wind pressure, to be forced to a greater inclination toward the leeward, thus causing a probable greater displacement of the center of gravity of train toward the leeward truss, and increasing the strain on the latter.

Vibrations and Strains.—In observing the deportment of a bridge as a swift train passes over, the parts are seen to be much agitated. Tie rods will often fly about at the middle parts to a very considerable extent. This has evidently received some attention by engineers, because in a few instances tie rods at the crossing points have been found tied together apparently to stop vibrations. That all such vibratory movements cause direct strains in the vibrating parts there can be no doubt; and it is unfortunate that these vibrations cannot be predetermined so that the strains resulting from them can be calculated. Could these be accurately determined, it is probable that the practical maximum working stress for bridge iron in tension could be safely raised from 10,000 pounds per square inch to 15,000 pounds; a margin being still left between the latter figure and that for the elastic limit for indeterminate strains due to such movements as considered below.

Lurching of the Bridge.—In some cases the whole central part of the bridge is also in an agitated condition, both vertically and horizontally. There seem to be various causes for this, such as want of perfect balance in the drive wheels and connections, error in perfect alignment of rails, especially in the vertical plane, wandering of the wheels from side to side over the 1" to 1½" of clearance between flanges and rails, irregularity of curves on bridges, tangent points on bridges, etc. In some cases this seems to amount to an oscillatory or vibratory movement of the whole bridge.

A Bridge Indicator.—In order to study these effects more satisfactorily, as well as the "dynamic effect" of a moving train upon a bridge, an instrument has been devised which might be called a *bridge indicator*, the object of which is to give a graphic record of the movements of a bridge as a train passes it. A rude affair of the kind has been used with results given below. In this case a bridge near Columbus, Ohio, was chosen as the subject of experiment with the instrument, it being the only one yet experimented with. This particular bridge was a "pony," or "half Howe" truss, of two spans, both upper and lower chords being continuous over the central pier. Each span is 60′ 6″ long, with a total depth of truss of 8′ 9″. The chords are of three timbers, 5″, 10″, and 5″×12″ in section for the lower, and 5″, 10″, and 5″×9″ for the upper chord. Main braces are 6″×8″, and counters 6″×6″.

The upper diagrams of 1, 2, 3, &c., were all taken at the middle of the west span of the bridge. The lower diagrams, of the same numbers, were taken at the middle of the west half of the west span. Thus, any two diagrams under one number were taken simultaneously, the upper at the middle and the lower at the quarter of span.

The track on this bridge was straight, except at the west end, where ten feet belong to a curve of about four degree. Thus, a tangent point lies in about ten feet from the west end. The object of placing an indicator at the west quarter of the bridge was to observe the effect of this tangent point.

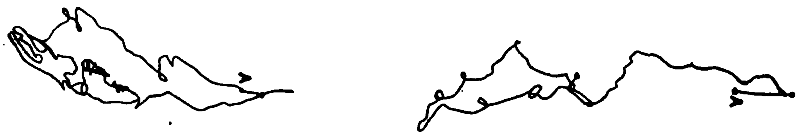
A description of the instrument will aid us to a better interpretation of the diagrams. At each point for taking diagrams a wooden board, dressed smooth, was secured to the bridge firmly at one truss. The plane of the board was vertical and perpendicular to the line of the truss. A paper was secured to the board by thumb tacks for each diagram. Upon these sheets while thus tacked to the boards the diagrams were made. At the midspan the paper faced toward the east, while at the west quarter it faced toward the west. From the ground beneath the bridge a stand was built of timbers and brought up to where a pencil could be firmly held by it, and in such position as to lightly touch the paper tacked upon the board secured to the bridge, as above described. Under these conditions a movement due to the yielding of the bridge in any manner would be indicated by a mark of the pencil upon the paper. A vertical deflection of the bridge would make a vertical mark equal in length to the deflection. Also a horizontal movement would be indicated by a horizontal mark, or, finally, any sort of cross motion of the bridge at the indicator would be evinced by its representative mark. In other words, the bridge autographically registers all of its own transverse movements.

The same figures would be obtained, evidently, if the paper were held upon the stand and the pencil upon the bridge, except one would be inverted with respect to the other. The most natural arrangement is the latter, and for that reason the diagrams are so posed that a downward motion of the bridge is indicated by a downward stroke of the pencil on the figure. The figures of the plate are enlarged 2.7 times.

No. 1 was taken at the middle of the bridge when a slowly moving freight

train was passing, drawn by an ordinary-sized locomotive. The pencil was held on the paper till about ten cars had passed going east. The bridge sank gradually from A to C as the engine approached the middle of the span. But as it passed on over, the pencil rose to D, and remained there till about five of the heaviest loaded cars passed. For the lighter cars following, the pencil rose to E and remained there for the next five cars, and it was then removed.

No. 2 is for a freight train going west at about twenty miles per hour. A is the position of the pencil when the bridge is at rest. As the engine came upon the east span the pencil rose from A to the top of the figure, and then descended again to the bottom as the engine came over to the middle of the west span where the indicator was located. Then the pencil rose to the top of the open part of the figure when it was removed, the engine having just left the bridge. The lower part of No. 2, taken at the quarter, had the pencil in contact longer than the upper part; the heavy blotch at the top of the lower third occurring while the cars of the train were passing.



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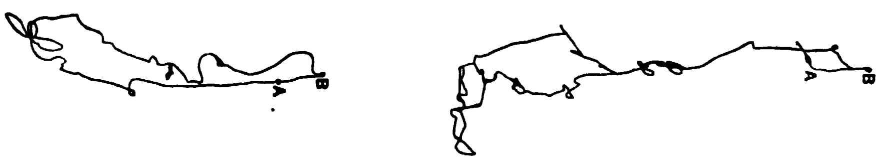

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No. 3 resulted from the passage of a passenger train of four cars going west. As the train struck the east span the pencil rose from A to B, but descended as the engine came upon the west span to the lowest point, it then rose to the heavy markings at the middle. Finally the pencil returned to A.

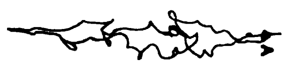
No. 4 is for a passenger train going west. As the engine came upon the east span the pencil left the point of rest A, rose to B while engine was on east span, went to lower part of figure as engine came on west span, but finally returned exactly to A as the train left the bridge.

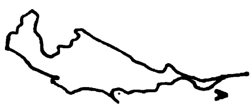
No. 5 is for a passenger train going east, four cars. Pencil went down to lower point as the engine was on the west span, then it rose as the second span was reached, and finally went above A to B as the rear of the train was on the east span. But the pencil finally returned to A as the train left the bridge.

No. 6. Passenger train, two cars, going east at about thirty miles per hour. Pencil was removed just as the last car passed it. This explains the absence of the point B. A variety of small movements must have occurred when the pencil was about at the middle of the diagram, thus giving cause for the black blotch.

much so as would be naturally supposed. They do not add much light respecting the influence of the tangent point on the west quarter of the bridge. Also the relation of the movements of the bridge at the two points does not appear to be systematic in detail, though bearing a general resemblance as above stated.

Much interest attaching to these diagrams is obscured in the knotted points. To remedy this it is proposed to arrange a clockwork to carry the paper forward, at a predetermined speed, while the diagram is making. Then if the number of cars in the train is noted, and if the instant at which each end of the train passes the indicator is marked by a dot on the moving diagram paper, we will, by knowing the speed of the paper, have data for miles per hour of train, and or-





No. 7 was taken as a pony engine passed very rapidly going east. The pencil was removed as the engine reached the middle of the span. This explains why B is missing. The lower part of No. 7 is a more simple diagram than any of those taken at the quarter, though the pencil was not removed till the engine passed. This is due to the fact that the engine was alone. This card gives us a complete loop, the pencil returning to A.

The diagrams from the quarter point add but little interest. They resemble the others both as regards general form and in having two points A and B. They are smaller than the others, but not so

dinates for every position of train. But on the paper we should have two curves traced, one for the the vertical movements of the bridge, and one for the horizontal. This would give us the means of completely analyzing the obscure parts of the diagrams.

Simple lurches would be indicated by irregular sinuosities without law, while for vibrations they would be systematic.

One drawback to the general applicability of this instrument would be found in the inconvenience in erecting the tower for carrying the pencils. As a substitute for the tower, it is proposed to throw out a stone anchor from the desired point of application to the bridge, the anchor having attached a hempen cord or fine wire long enough to extend up to the point of observation. A pencil is then to be arranged in a slide working freely in vertical guides, to which slide the wire is to be attached. A spring, quite flexible, is then to draw up on the slide making the wire below tense. Then as the bridge rises or falls the wire causes the slide to remain at a constant height, while the instrument and paper are vibrating with the bridge. It is then only necessary to place the pencil to the paper, and the clockwork in motion, to secure the diagram for the vertical movements.

The lateral movements are not quite so easily provided for since there is need of an anchorage at one side on a level. It is believed, however, that this can be secured in effect by two anchors and chords, the latter forming a junction at the horizontally opposite point desired. To hold them, a tension stand under spring action, drawing as a resultant force to the two anchor chords, will fix the junction point as desired. In case of such double anchorage to the lateral and vertical, two pencils may be made to write on the one sheet or ribbon, and thus one clockwork answer the purposes fully.

Such an instrument with conveniences for anchorage could be applied to a bridge in a few minutes, and inspectors could obtain an autographic record of the degree of agitation of any and all bridges examined.

Such diagrams would evidently throw much light upon the vibratory effects due to unbalanced locomotive drivers, and indicate whether cumulative impulses from such parts of the train ever cause dangerous vibrations of whole structures.

Indicated Dynamic Effect.—The diagrams presented are not sufficient in themselves to serve this purpose fully and satisfactorily. Their appearance might, however, suggest some amount of vibration or oscillation. Referring to No. 7, first part, remembering that the pencil was removed as soon as the engine reached the midspan, we observe some evidence of lateral vibration as occurring simultaneously with the sinking of the bridge. But as to the vertical movements, we see almost no trace of repetition of any part of the movement as would be likely to occur if the bridge vibrated in going down, except, perhaps, in a slight degree in the loop in the bottom. This loop is about one-eighth of the depth of the diagram. The lower part of No. 7 indicates almost no vertical vibration in any part. Loops at the bottom of Nos. 6, 5, and 4, indicate vertical vibration, also of about 22, 14, and 10 per cent. of the depth of the diagrams respectively. Taking a half of these amplitudes as the increase of deflection due to dynamic effect, and comparing with the diagrams diminished by the same, we obtain the percentage which the dynamic is of the static effect, as 7, 12, 8, and 6 per cent. respectively, as due to the above measurements. Some of the lower diagrams give evidence of about the same percentages. The mean of these percentages is only about half what is required by some railway companies to be allowed for spans of the same length, viz., 60 feet. As given above in speaking of usual practice in this matter, it is about 15 per cent. for 60 feet spans. But it is always necessary to provide not for average, but maximum stresses in such cases. Hence the maximum 12, is close enough upon the 15 of practice.

Nos. 1 and 2 are both from freight trains, and give evidence of almost no vertical vibration. Also the total deflections, counting from the points of rest A, are less for the freight trains than the passenger trains in Nos. 3 to 6. If, however, we add the above twelve percentage of dynamic effect to the deflection in Nos. 1 and 2, we obtain very nearly the same strains as are actually due to passenger trains; and singular enough, as obtained in actual practice by computing static effect of freight trains and adding the stated percentage for dynamic effect.

These facts, though corroborative of the real existence of dynamic action or impact, yet at the same time they testify to a somewhat excessive allowance for it by practical engineers. But before drawing conclusions in this way for guiding us in practice, it is necessary that much more extensive data be procured and worked up.

As regards lateral vibration, the first two numbers on the plate are narrower than the rest, the same being taken from passing freight trains. The others are for passenger trains, except the last one from a rapidly moving pony engine. Hence it appears that fast trains cause much the greatest lateral disturbance. The resulting effect upon the lateral bracing is a matter of interest. By measurement of the widths of the diagrams taken at the midspan, it is found that the total lateral movement for passenger trains is 42 per cent. in excess of the like movement for freight trains. May not this call for careful attention to the subject of dynamic effect upon lateral bracing?

Testing and Selecting Material.—In the selection of material for bridges, great care is exercised by bridge companies, much greater, indeed, than is usually supposed by the mass of people who ride over their bridges. Some bridge companies make tests of the materials not specified or required by the railway companies ordering. For instance, the Detroit Bridge Company examines all the eyebars for a bridge by piling a quantity of them and passing the pin through the eyes at opposite ends simultaneously. Any bar preventing the passage of a pin is thrown out. Then the bars are individually tested to a tensile strain of 15,000 pounds per square inch, and again the pins must similarly pass. If any eyebar has stretched so as to prevent the passage of the pin it is rejected. Such a practice would discover hidden flaws, and would pay if discovering such flaws only at the rate of one in a hundred bridges. A flaw which would probably have been made known by such a test was actually discovered by the road master of the Baltimore & Ohio Railway in one of his iron bridges, and the piece had to be removed. A first-class catastrophe might have here resulted except for the keen eye of the road master. There are those who object to straining iron going into a structure, especially beyond the working load. But a test which will discover the few hidden flaws that would otherwise pass unobserved, will probably more than offset imaginary evils due to strains which, though within safe limits, are somewhat in excess of the adopted working load. Accordingly, this test is believed to be a most excellent one, but of the few bridge companies conferred with in regard to it by the writer, it has been found in use only in the one instance named.

All companies do more or less testing with testing machines, including pieces ranging from small "test specimens" to full-sized bridge members. Tests for tensile resistance are by far more plentiful than compressive, but a good number of the latter are on record including full-sized bridge columns. It is a quite common practice, however, to test a piece taken from a large bar rather than the whole bar itself. Large bars are thus found to have a lower tensile strength than smaller rolled bars.

Testing-machine tests for tension, to meet the present demands of bridge builders and companies, must make known at least three quantities:

1st. The elastic limit.

2d. The ultimate strength.

3d. The percentage of total elongation of some specified portion of the original bar—usually about eight inches.

In some cases the greatest reduction of section is noted, and by some this item is preferred to the percentage as above.

As regards the elastic limit, it is found not to be perfect, that is to say, some permanent elongation is always experienced by good iron before arriving at what is usually adopted for that limit. But practically these elongations are nearly proportional to the increments of load, and extend nearly through the whole range of loading up to the so-called elastic limit. Beyond this limit, however, they rapidly increase. The point where this change takes place is noted as the elastic limit. This limit, thus found, is given a more rational showing from the fact that, if at any point within it, the strain be relieved and then restored, no further permanent elongation is experienced till after passing the previous condition of strain. At points beyond the elastic limit, however, this is not the case. An extended examination of iron specimens will verify the following facts:

1st. Bars immediately from the rolls, which have not been subjected to jars or other causes of strain, will experience permanent elongation at very slight tension. This is true also of bars direct from the annealing oven, even though they had previously been subjected to violent mechanical action. In these cases there appears to be no limit of perfect elasticity.

2d. A gradually applied and removed tension within the usually accepted elastic limit produces a permanent elongation, which will not be increased for like or less tensions as above stated. This is also true of compression.

3d. A specimen which has been strained, as indicated in 2d, will take a permanent set for a slight reversal of the strain.

4th. At the point where the permanent elongations cease to be nearly proportional to the increments of load, or to the elastic elongations, we find the usually accepted elastic limit. Some of these facts can be verified by simply straining a piece of annealed wire by hand.

But the most common tests in use among bridge builders, and which are at once both invaluable and fortunately of easy application by any blacksmith, consists,

1st, of bending a bar 180° degrees around a cylinder whose diameter equals the thickness of the bar, and which the bar must stand without fracture to be accepted;

2d, of nicking a bar on one side with a cold chisel, and bending it similarly as in 1st, with the nick at the bow of the bend, when it will usually break, showing a fracture which must be fibrous and free from glistening points or faces. Very frequent use is made of these tests in the smiths' workshops where waste pieces of bar ends, which have no other value except for scrap, are put to a most valuable service.

Heads of Eyebars.—In the manufacture of one very important part of iron bridges, viz., the eyebars, a number of methods are in use. One consists of forming the heads by a separate operation, and then welding them upon the bars. The weld is made close to the head without upsetting the bar near the the welding point. This must certainly reduce the sectional area of the bar at points so near the weld as to be heated but not worked, because the heat cannot be taken without corroding the iron, and thus eating away a small portion. But where full-sized bars of this kind have been tested to destruction, it appears that the rupturing point is always at some intermediate part of the bar considerably removed from the head, thus proving the reduction by burning to be unprejudicial. This practical ignoring of the slightly reduced end sections appears to be due to the influence of the enlargement of this head. This conclusion is verified by experiments in tension on extended necks of wrought iron, the fracture always occurring at some intermediate point in the neck.

In other cases heads are formed on the bars by welding several thicknesses of iron upon the side of the bar, thus giving a sufficient body of metal to form the eye. The reduction of section, above mentioned, by fire corrosion will take place here also, but actual experiment has shown it to be without objection, for reasons above given.

Stone Arches.—Of stone bridges there are some fine ones in the State, particularly on the Lake Shore & Michigan Southern Railway, the Baltimore & Ohio, and the Cincinnati, Cleveland, Columbus & Indianapolis. The former has four or five large stone-arch bridges, two or three of which are two span, and they run from 40 to 80 feet diameter. Also one beautiful two-span skew arch of about twenty feet diameter. At Bellaire, the Baltimore and Ohio Railway has a remarkably fine stone viaduct, consisting of thirty-seven semicircular arches of 28 feet diameter, supported on piers 6×12 feet. The height of the copings above the streets of Bellaire is 32 feet. Twenty of these arches are in a straight line, and seventeen on a four-degree curve, all in dressed stone.

Stone Quarries.—In the selection of stone from Ohio quarries for important structures, care is needed lest a soft stone be taken which will not stand the weather.

The Roadway.—Ordinary railroad lines consist of four parts, viz., *bed*, *ballast*, *ties* and *rails*. A cross section of the most perfect roadway found in Ohio

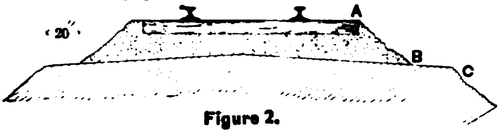


Figure 2.

is given in Fig. 2. The Pittsburgh, Fort Wayne & Chicago Railway has some seventy miles of it, so fine in its outlines as to be truly a work of art. It is, indeed, unfortunate, that all passengers cannót conveniently see it from the moving car. Observed from the rear car of a train, it appears like a beautiful striped ribbon stretching away in the distance. Across the top the stone ballast is just to the upper surface of the ties. At A a definite line of intersection is formed. At B is another, and also at C. The slope, AB, is as perfect as though the ballast had been piled under a board. The limit of ballast at B is by a single row of ballast stone between egg and nut size, and individually laid by hand. The upper surface of the bed is crowned or convex, as shown in the figure. The part, BC, is all patted smooth with shovels. A weed is not allowed. The ballast is broken stone where this form of bed is found. The road, however, has not all stone ballast, though the amount is increasing from year to year.

Other roads have considerable portions laid with stone ballast, that ballast being much sought after. Cinder or slag from furnaces is also employed, it being preferred to some kinds of stone.

Some Ohio Stone is entirely unfit for stone ballast, and does not pay for hauling it from positions of convenient proximity. It pulverizes in use. Limestone is said to be the preferable stone. In considering what material shall be declared the best ballast, it appears that a best ideal ballast must be heavy enough to not be easily disturbed when laid, and to hold the ties in ballast; it should not be too fine nor too coarse, say about egg size; it should have sharp angular corners to hold the ties, and it should be impervious to water, so as to dry out quickly for preservation of ties. Probably the best possible material for uniting all these conditions is broken glass. It weighs about the same as limestone. Glassy furnace slag comes very near to it. Sandstone is the poorest of all stone, since it wears rapidly so as not to hold the ties, and it absorbs moisture, and holds it to the rapid decay of the ties. But impervious stone allows rainwater to run directly through the ballast to the bed by trickling down the surface of the fragments and without absorption. On reaching the bed it flows off to the right and left, if the bed is sufficiently crowned at its summit. In the best practice it is actually crowned for this purpose.

The minimum depth of ballast shown in Fig. 2 is six to eight inches under the ties. It often actually exceeds this, sometimes to the depth of several feet. Two reasons are given for this, first, a new bed settles causing inequalities of grade; and, second, inequalities of grade admitted in new roads are, to a considerable extent, equalized according to growing importance of road. In these cases, rather than add new bed material to revive settling annoyances, ballast is piled on.

Ties.—Ties used in the State are mostly oak; the best being obtained from Virginia, and known as "Virginia ties." They are of white oak and run from 10″ to 12″ width. Chemically treated ties of elm and some other woods have been used to some extent. The number per mile varies between 2500 and 2800.

Slip Sides.—In a few instances "slip sides" have been encountered in which the whole fill, or embankment for a length of one or two hundred feet, will gradually be carried laterally out of place. These are found very difficult to manage. In one case, on the Baltimore and Ohio Railway, a filling of coal slack was used after several editions of earth filling had been carried away. The coal stood very well, its less specific gravity being supposed to be the cause. In some cases piles are driven, the idea being to "pin" the slipping bank to place. But these pins often get badly demoralized from the great pressure. Springs of water are usually found along the upper limits of these slipping sides.

The Track Line.—The alignment of the track on curves often gets deranged to a surprising extent; in one case over forty per cent. by measurement was the degree of curvature raised. One instance, on the New York, Pennsylvania and Ohio Railway was noted where a curve carried the train badly. Several unsuccessful attempts were made to correct it by throwing the track by eye. Finally the curve was re-run with instruments and found badly out. In many cases the track has been observed to be appreciably deranged where measurements were not taken.

Such derangement occurs by the working of section men on the road, as in re-adjusting grade, or outer rail elevation; in placing new ties, rails, etc. Tangent points undoubtedly "creep" from this cause, the presence of them a few feet in upon bridges, as noticed in a few instances, being apparently due to it.

Track men should have some easy and simple means of ascertaining the deformity of curves and the proper "elevation of the outer rail." For the latter an extraordinarily simple and efficient device was found in force on several roads, viz.: a cord or string of certain length, say 60 feet, and a rod; the former being stretched as a cord to the curve, the versed sine, measured on the rod, is the elevation of outer rail. Some use 63 feet, and others less for the cord length. For the 63 feet the elevation is right for about a 36-mile speed.

In this device we find the suggestion for a curve corrector, viz.: at all points of an ordinary curve the versed-sine, for the 63 feet cord, should be of constant value.

In regard to the tangency of straight and curved portions of track, the usual practice is to make the curves true circle arcs, and exactly tangent to the straight parts. A little consideration, however, will show that instead of this, the path described by the center of gravity of a car should preferably have its corresponding parts thus in true tangency. But this cannot be where the outer rail is elevated or inner one depressed, or both, because in tilting the car for this difference of rail elevation the center of gravity is thrown in, and passes around the curve on a circle arc several inches within the circle which is truly tangent to the straight parts of the path. This has the effect to give a jolt to the car on entering on a curve. But, in practice, this is compensated in a measure by commencing the elevation of rail on the tangent itself at some distance from the tangent point, and bringing it up to the full value at or near the tangent point.

The object of making a difference of rail elevation on curves is to make the resultant of gravity and of centrifugal force take a position which shall be normal to the floor of the car. To secure this result perfectly, in every respect, it is evident that we can neither begin the elevation on the tangent nor admit of anything less than full value on the initial part of the circular curve. Neither should there be any offset, sudden or gradual, in the path described by the center of gravity of the car, such as above mentioned as due to rail elevation. Abrupt disturbances in the direction of this resultant would be perceived as jolts toward one side or the other. It is evident that the direction of a disturbance which would be least noticeable to a passenger, or have the least tendency to derail a train, would be vertical, and hence this is the most admissible. But it appears impossible to preserve quietude in every respect in a car, even though the resultant force above named could be maintained truly in the normal position indicated, because the car must be rotated on some longitudinal axis to the extent of the difference of rail elevation. This necessitates an elevation of one side of the car, depression of the other, or a compromise action, the latter being probably preferable. Hence one rail must be depressed as well as the other elevated, the best condition being obtained when the center of gravity of the car is neither raised nor lowered.

Under these conditions, viz.: first, maintenance of perfectly normal resultant; and, second, a slight rotative movement of the car on its longitudinal axis, we secure the least possible disturbance. Then the only sensation to a passenger, if indeed any be possible in going round a curve at the proper speed, would be that of slight lifting or lowering, as depending on sitting at the lifted or lowered side of the car.

But it is clearly not possible to realize these conditions when a straight track is, according to custom, changed abruptly to a circle. Not even though the circular curve and tangent belong to the center of gravity of the car, instead of the middle line of track. The only way to fulfill the conditions indicated appears to be, to gradually increase the curvature from the tangent to the circle by an intermediate curve of varying curvature. This we will term an *easement** curve; the main circular curve beyond the easement curve being called the principal curve.

* Called curves of "*easing changes of curvature*," and "*curves of adjustment*," by Rankine; also "*spiral curves*," by others. See *Rankine's Civ. Eng.*, p. 651; *Railroad Gazette*, Dec. 3d, 1880; recent articles in *The Engineering News*, etc.

Now the easement curve must, throughout its length, maintain perfect continuity of proper relation of the radius of curvature and rail elevation. That is to say, to meet the above conditions, the radius of the easement curve must change from point to point; and the rail elevation at any one point must be precisely that required for the radius at that point. This relation of elevation and radius is well known, viz: the elevation is simply in the inverse ratio of the radius. Or, again, the product of the elevation and radius of curvature is a constant for any given number of miles per hour for speed of train. This is true whatever the form of easement curve, and hence the latter is neither determined nor influenced by that relation.

Being free to assume the law of the easement curve, it appears that the very best conditions possible to adopt for fixing it are to assume, first, that the car, in tilting to the difference of rail elevation as it passes along the easement curve, shall rotate about a longitudinal axis passing through the center of gravity of its cross section, and, second, that it be accelerated in that tilting movement, so that a passenger at the side of the car shall experience only the sensation of a slight change in his own weight while on the easement curve. That change of weight will be an increase if outside and going from the tangent, and *vice versa.* This change of weight, however, should be made imperceptible, and it is believed so to be when arranged as below.

This makes the law relating to the time and rail elevation identical with that of falling bodies, or with

$$h=\tfrac{1}{2}ft^2$$

where h is the elevation, f the constant acceleration, and t the time. Now suppose that in running this easement curve, 50 feet chords are adopted$=c$.

Let the number of chords reckoned from the tangent point$=n$. Also assume that at 400 feet from the tangent point the elevation of one rail over the other be 12.8 inches. Let the number of chords passed per second by a passing train be $t=nc$. Substituting these values and reducing for a velocity of 30 miles per hour, we obtain

$$h=0.2\,n^2$$

From this we obtain for

$n=$	1	2	3	4	5	6	7	8
$h=$	.1″	.8″	1.8″	3.2″	5.0″	7.2″	9.8″	12.8″
$R=$	17190	4297	1410	1074	68.8	478	351	126

n being the number of 50 feet chord lengths from the tangent point, R the radius of curvature, and h the difference of rail elevation in inches, for a track gauge of 4′ 8½″.

For a speed of 45 miles per hour, for the same radii, R:

$n=$	1	2	3	4	5	6	7	8
$h=$	.36	1.4	3.2	5.7	9.0	12.8	15.4	22.8

It is observed that the radii are the same for all cases. This makes the easement curve the same curve for all speeds, the allowance for different speeds being made in the elevation. Hence the curve can be laid out from the same set of deflection angles, computed once for all.

In a particular case of practice, the easement curve is to be continued to where the radius equals that of the *principal,* or main circular curve; when the latter is to be run tangent to it in continuation.

Now these curves should be understood as forming the proper path for the center of gravity of the car, and not the center line of the track. For greater convenience to passengers, however, it should be the path to the center of gravity of the load of passengers. But as these centers do not differ much in position, they may be assumed coincident.

Assuming this center of gravity to be at a height above the track equal to the gauge of track, viz., 4′ 8½″ usually, it appears that in order to make the path of that center of gravity describe the easement and principal curves above laid down, it will be necessary that the curves, when first laid out on the ground, must be moved outward at each point a distance which just equals the difference in rail elevation, h, at that point. This is to provide against displacing the center of gravity as the car tilts to the difference of rail elevation.

Hence, in practice, run the easement curve as above, till its curvature equals that of the principal curve. Then set out each point the amount h proper to it as rail elevation. Then continue on the principal curve. In laying the track depress the inner rail, the same amount that the outer one is elevated, both together being h. This is to be done for that speed of trains at which it is desirable to have the most perfect freedom from all manner of disturbances.

In compound curves not reversed, the easement curve should be introduced to give a gradual change of curvature, rail elevation, &c., from one curve to the other. In reversed compound curves, the easement curve and elevations should be used to change from the first principal curve to where the track would run off on a straight tangent, and then it is to be run, in the inverse order, to where its curvature equals that of the second principal curve, &c. In short, every portion of principal circular curve should begin and end in an easement curve, as described above.

This gives perfect freedom from side jolts and a probably imperceptible vertical lift or decadence. To give an idea of the latter effect, that is to say, of the apparent gain or loss of weight, suppose a man of 200 pounds weight to be at the extreme side of a car, and that the car enters upon the above easement curve at 30 miles per hour. The accelerative lifting or depressing force due to the 200 pounds weight will be, by calculation, only 0.16 of a pound, or about 2½ ounces, an effect which would influence the cushion of the car seat less than to place an orange in the rider's lap.

But all the above refinements respecting the alignment in the horizontal plane will be of but little avail where the importance of the vertical alignment is ignored. From an extended examination of track, both by sightings from the ground, and by taking advantage of opportunities of riding miles within one or two hundred feet of a second track, and of allowing the two lines of rail to spin through a fixed gaze with a view to observing the relative heights of the two rail lines, it is believed that the error of vertical alignment is usually at least five-fold greater than in the horizontal.

Of two sections of road, if one should be found as badly out in the horizontal alignment as the other in the vertical, each otherwise correct, it is altogether probable that the section boss of the former would get his discharge the first time the road master came along, while the other would very likely be commended. But in this case the wrong man is discharged, because, as to the riding qualities of the two sections of track, the former would be far the best. This fact is evident by observing that the weight of the car is sure to cause it to follow all inequalities in the vertical alignment, while most of the lateral deviations of the rail will be skipped, and pass without effect. But even if followed to detail, in both instances, the vertical deviations will rock and tilt the car badly, and cause disturbances which will be magnified by the height of passengers or freight above the track. To explain, suppose one rail perfect in line, and the other to rise and fall one inch, in distance of fifty or a hundred feet. Here one wheel has a latitude of vertical movement of one inch. The straight rail forms an axis to this motion, and if a circular cylinder, of radius equal the track gauge, be drawn to this axis, cutting the car lengthwise, every point in that cylinder would have the one inch of motion. That is, a point vertically over the straight rail, at the height of track gauge, would move sidewise one inch when the wheel on the opposite rail rises and falls one inch. Persons in seats directly over the straight rail receive the lateral jolts of about one inch. But persons in the seats at the opposite side of car receive jolts which are both vertical and lateral to the extent of about one inch, which amounts to a diagonal jolt of about one and a half inches. The top of the car may, at the same time, be thrown two or three inches.

This supposes one rail straight, but it is as likely to be cut as the other; both sometimes together and sometimes opposite. In case both rise together one inch, the car receives the vertical displacement bodily of one inch.

But when they are in discord, the passengers are thrown to an extent nearly double that due to the single rail error above. The consequent jolting annoyance cannot safely be prevented by rigid car-couplings, because the strains would be great upon the couplings, and no coupling attempts it.

But now suppose equal inequalities in the lateral direction or in the horizontal alignment. The wheels would skip most of them, the tendency being to go nearly straight ahead rather than turn out for all side-crooks in the rails. This is rendered possible by the clearance between the wheel flanges and rails. The cars are prevented, to a great extent, from wandering from side to side of the clearance by use of couplings, which offer a considerable resistance to the lateral movement of one car end, crosswise to the one coupled to it.

From these facts it appears that the vertical alignment is the one which demands the most careful attention for exactitude, while in practice it seems to receive the least.

"Low joints" are found everywhere, though in the most carefully guarded track they are slight. Where the "fish plates" are allowed to get loosened, the wheel pressure and peneing action bend the rails to an arched form. Small "joint ties" also favor low joints.

If the rail joint could be given the same stiffness as the body of the rail, and then if the bearing of the ties upon the ballast could be uniform along the rail line, the rails would remain straight. The "angle bar" is superior to the fish plate for making a stiff joint; but as no joint in use is as strong as the body of the rail, it follows that the deficiency should be made up by a greater amount of tie bearing near the joint. There are many advantages in the so-called "suspension joint." It is formed by placing the abutting ends of the rails over a space of about ten or twelve inches between two ties, so that the fish plate or angle bar will span the space, and be secured upon the ties. The advantage of this in the matter of low joints consists in the greater amount of tie bearing upon the ballast at the locality of the joint, and due to the fact that these two ties are nearer each other than other ties along the rail. But still the tendency is to low joints, and it seems necessary that, in laying ties, the two widest ones be selected for the pair at the suspension joints. This, together with closely-fitting angle bars, it is believed will maintain freedom from low joints. This is based upon the supposition that the ties along the middle portion of the rail be all smaller than the joint ties.

But, in actual practice the joints in one line of rails are sometimes placed opposite those in the other line, and sometimes the joints alternate. Some road masters strenuously insist on opposite joints, others equally so on alternate, and each will have no other. This is the one thing about railroads on which there is found the greatest prevailing difference of fixed opinion.

Now, respecting the bearing of the joint ties upon the ballast, 1st, when the joints are opposite, we find that the selected wide ties, which become joint ties for one rail line, are also in proper position to serve as joint ties for the other line. This also leaves the middle portions of the rails resting on the smaller ties, a condition pointed out above, as favorable for preventing low joints. But when the joints are alternate, the wide ties selected must be twice as numerous, and consequently differing less from the remaining ones; but besides this we find that the wide ties for the joint at one side extend across, and become wide ties at the middle of the opposite rails. This favors low joints, as pointed out above, and is one reason why alternate joints should be avoided.

But some contend that alternate joints ride more easily and pleasantly than opposite. This is probably true for equal degrees of low joints, but it seems to be an open question whether the alternate joints, with their greater tendency to low joints, will carry trains more smoothly than will opposite joints well laid on the selected joint ties. But on some roads very little if any attention is paid to selecting joint ties. In such case it is probable that alternate joints will ride smoothest.

It might be supposed that alternating low joints would give an oscillating motion of car from side to side, and opposite joints a vertical oscillation. The latter is likely to occur for speeds under about twenty-five miles per hour. But in high speeds the time between joints is too small for serving as a period of vibration or oscillation. Hence it cannot take place. At thirty miles per hour, alternate low joints appear to be entirely without effect for all oscillation, and is not noticed at even twenty or perhaps fifteen miles per hour.

From these facts it appears that low joints can be more effectually avoided when opposite, but will have less prejudicial riding qualities when alternate.

Rail Sections and Weights.—The form of rail section is a matter of considerable import. The prevailing modern form is nearly like No. 1, Fig. 2*a*, while some of the older rails in use in the State are nearly like No. 2. Various devices have been used for making the

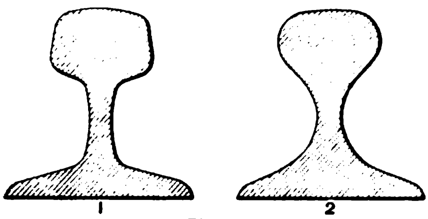


Fig. 2 *a*

joint in No. 2, but it is a hard rail to hold. Fish plates and bolts soon release their grip. The bolts are apt to break, but they first stretch and loosen the plates. Then the plates, rails, and bolts wear badly, because the form of section is seen to not be favorable for holding a fish plate. On the other hand, the upper and lower parts appear much as though they would serve admirably as wedges to spread the fish plates and tear the bolts. In some cases wood is used on one side, and sometimes both wood and iron.

But the nearly square shoulders between the head and foot in No. 1, are seen to be especially well adapted to hold a fish plate. Even a little looseness under the fish-plate bolts would not admit of very much vertical displacement of one rail on the other at the abutting ends.

Rail weights vary on Ohio roads from 50 to 67 pounds per yard, the most common being 60. It is often the case that heavier rails are laid on curves than on tangents. This is to provide against the greater wear on curves.

Lock Nuts.—In spite of the fact of numerous existing lock nuts of merit, none seem to meet all the requirements for fish-plate bolts. The simplest found in use is the Verona lock nut. It consists of a split and offset ring of steel, tempered to a spring, and having cutting points at the split. It appears to be made of quarter-inch square steel, cut and bent nearly to a ring, but having an offset of about one-eighth inch, where the ends nearly meet to form the ring shape.

Wear of Rails.—Practice develops the fact that the outside rail on curves becomes by far the most worn. In some cases the outside worn rails, and inside nearly perfect ones, are interchanged, so that each shall get its portion of wear. The wear now referred to is mostly on the side of the rail head. The tops of the heads also become much worn. Altogether the wear on curves is much in excess of that on tangents, a fact which accounts for laying heavier rails on curves.

The fine theory of the "coning of wheels" is entirely without force in practice. Wheels wear most near the flanges, so that in a short time the effective coning is reversed; that is, the wheels become smaller in diameter of tread at points near the flange than at points remote from it. It seems evident that the more wheels become thus worn and lose their coning, the greater will be their tendency to climb outward on curves, and consequently the greater will be their slip and the greater the wear, not only of wheels, but also of the rails on curves.

The recent improvement in chilled car wheels of leaving an inch at the flange edge of tread, without chill, will doubtless tend to make the wear more uniform over the whole tread.

Switches and Frogs.—A great variety of notions about switches and frogs are found in vogue. For instance, some have decided preferences for the Lorenz switch, and others for the Wharton, where any other than the ordinary plain switch is desired.

The Wharton switch is the homeliest switch, probably, that was ever made. It would never get adopted from any good looks. But it has great advantages for certain positions in track. A remarkable property of it consists in its leaving the main line of track entirely intact or unbroken. This is secured by means of parts so formed and raised as to lift the wheels high enough to carry the flanges over the rails at the one side. In practice, both sides are raised. This raises the cars also in passing the switch, a requirement which could not be admitted at high speeds of train.

Hence it appears that this switch is especially adapted to places where trains are to pass at high speed along the main line, but where it is necessary to occasionally turn out to a side track, the latter being always at a reduced speed. Being a "safety" switch, it is well adapted for yards and all places of much switching at slow speeds. While the Wharton switch requires one sharpened rail, the Lorenz requires two. These are so fitted that they will lie close up to a whole rail, and receive a wheel from it. The Lorenz admits of two unbroken lines of rail, but one of them turns off to the branch track, so that one rail of the main line is cut. In this rail it becomes unnecessary to raise the cars in switching. Hence this switch is adapted to location where a train may continue on main line or take a branch at speed. This switch is made a safety switch by introducing a spring. But the spring is seriously objected to by some, with the statement that a stick or pebble may become engaged between the pointed and fixed rail, and thus throw a a train. Devices have been introduced for obviating this objection.

Beside the ordinary "frog," two others are found in use, viz.: the spring frog, and the self-acting frog. Some roads are very partial to one or the other of the two latter, while others will have nothing to do with them. The chief objection seems to be that the movements are apt to become obstructed by sticks, dirt, cinder, snow or freezing, &c. But on main lines, where turnouts are to be passed at speed, and on lines passing fifty to a hundred trains per day, a common frog is apt to become much worn in a comparatively short time. The spring and the self-acting frogs have far greater wearing qualities than the common frog, because they secure nearly the effect of an unbroken rail. Where switching is not frequent, and trains pass at speed, the Wharton switch and spring frog are good accompaniments.

Bridges on New Roads.—Economy in the management of railway structures favors the adoption of cheap wooden ones, such as trestles, pile bridges, &c., in the construction of roads, the same to be renewed in due time by more permanent ones. One important consideration in regard to this is the practical "waterway" under bridges. In some cases trestles, a few hundred feet in length, have been introduced at points of unknown water way, which have subsequently been reduced to a complete fill, with the exception of a tile opening. In other cases iron structures have been undermined by reason of a cramped water way.

The life of a wooden bridge is, perhaps, none too long for enabling the engineer to learn the actual demand upon any bridge location for the water way. In one instance, a fine Pratt truss of over one hundred feet span was placed over a nearly dry channel, at a height above bed of only about five feet. A stranger to the locality would wonder why the space was not filled with dirt, at a cost of almost nothing comparatively. But should he happen to be along at the one or two times a year when water was up, he would form an opinion, sound and correct, as to water way.

Cattle Guards.—This structure, though of seeming insignificance, is yet of very great practical moment. This is due to two facts, viz.: first, the great number of them required on a single road; and, second, that any one defective cattle guard is sufficient to wreck a train.

The amount of attention given to this matter by different roads varies greatly. For instance, they have been found built, except the "strings," of ordinary rail ties, and without much designing either. Some roads have an almost infinite variety, and most of them being built of such material and in such manner as is most convenient to the locality. Others will not only have a carefully designed and specified "standard cattle guard," for universal use, but will have material lying in their material yards all along the road, cut to specifications and ready for setting new guards, or for repair of old ones, on the plan of interchangeable parts.

The latter system reduces the matter of cattle guards to a basis of manufacture, with all its advantages of economy, stock on hand, &c.

The three most characteristic standard cattle guards, observed by the writer in the tours of inspection, are here described.

The standard of the Pittsburgh, Fort Wayne & Chicago Railway, shown in Fig. 3. A pit is first sunk nearly three feet deep, filled nearly one foot with broken stone. Then two square timbers, about $12'' \times 12'' \times 12'$ are laid crosswise the track at each side of the pit, and resting on the stone. On these, against the pit's banks, are laid, on edge, planks about 3″ × 12″ × 12′. Between these planks the "strings," about 12″ × 12″ × 6 or 8′, are placed one under each rail, as shown. The planks are heavily spiked to the strings, thus fixing the distance between the latter. The rails are spiked directly to these strings, the latter being chamfered. The fence, on either side, terminates about at A, as shown. An effort is always made to drain the pit by a channel, so that water scarcely ever lies about the pit timbers or mudsills.

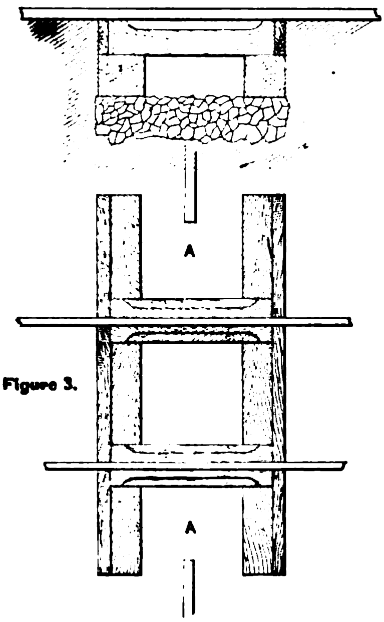


Figure 3.

In this guard the pit is generally left open, and is about two feet deep. Slats are sometimes put on, though this seems to be the exception.

The standard of the Cleveland, Tuscarawas Valley and Wheeling Railway is shown in Fig. 4. Two sticks, about 12″ × 12″ × 12′ are placed in the bottom of the pit, 8, out to out, crossing the rail line. On these are placed two sticks or strings, about 12″ × 12″ × 8′, one under each rail. On these last are placed 5 sawed ties 6″ × 7″ or 8″ × 8′ and notched on to a remaining depth of 6″. The outer ties are placed flush with the ends of the sticks on which they are notched. Against the outsides of the outer ties, and extending down by, partly over the ends of the strings, are placed planks about 3″ × 12″ × 12′ and spiked. Across the ends of the ties a binder or guard rail of wood is bolted. The rails are spiked upon these ties as on any other ties. The upper corners of the ties are chamfered.

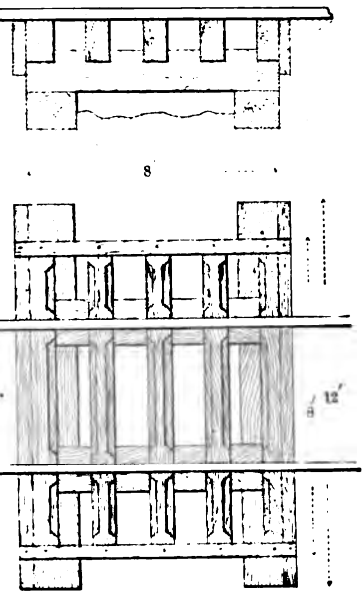


Figure 4.

This is believed to be a most efficient guard. Its cost, as compared with that of Fig. 3, depends mainly on whether the five sawed and chamfered ties, and guard rails and boats, of Fig. 4, cost more or less than the stone filling in the bottom of Fig. 3.

The Baltimore and Ohio Railway have a more elaborate and costly standard, shown in Fig. 5. In the bottom of a pit three mudsills are placed, each about 12″ × 12″ + 12′. Across and on these are laid the string pieces, one under each rail, and 12″ × 12″ × 8′. The ends of these are notched into 5″ × 12″ × 12′ planks, the outsides of the latter coming just flush with the two outside mudsills. The strings are chamfered, and the rails are spiked to them.

Slats or bars are counted an essential part of their guard, and they are provided for in a most ingenious manner. On the inside of each of the outer heavy

5″×12″ planks is spiked a $1\frac{1}{2}$″×8″×12′ plank, notched at spaces of about 12″. The notches are diagonal, so as to carry 4″×4″ bars lying in a diagonal position, that is, so that one corner of each stick

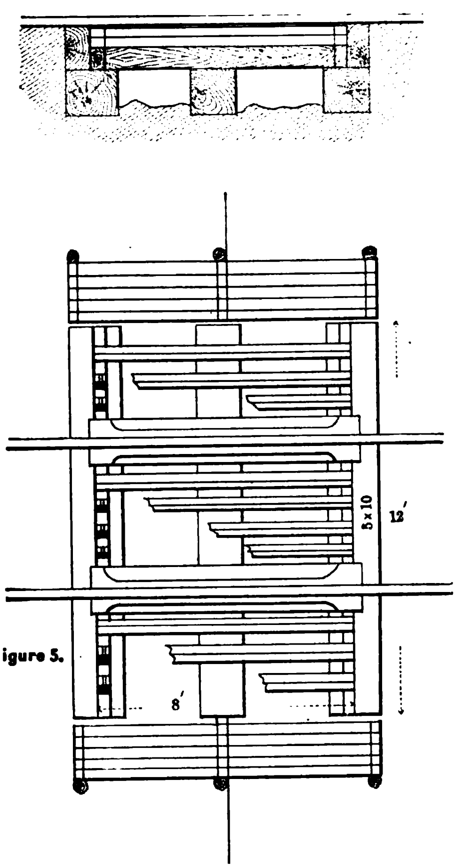


Figure 5.

is up. These bars are not nailed, because in a few months they sag, and are then turned over. As often as any one sags it is reversed.

At each side of the track, or end of the guard, is placed a half length of fence as shown, from which starts out the division fence to which the cattle guard belongs.

Nothing would seem to be more efficient than this as a cattle guard, and yet the road master states that in one case a certain man's cow had educated herself to such a point of excellence that she would deliberately and safely walk the champered stringers, placing right feet one side and left feet the other side of the rail. But this isolated instance of successful climbing cannot be considered due to any fault of the cattle guard.

Grade.—The steepest grade noted by the writer is 85 feet to the mile, though that is very likely exceeded in the State. Very little attention appears to have been given to controlling grade; or least possible maximum grade per division, or other portion of road. Neither to the matter of grade compensation for curvature. These questions appear to rise to great importance only on long stretches of road through uninhabited country like our western wastes, where it is not convenient to locate "helper engines" for an occasional excessive grade.

But in Ohio, a road master will reply, stating the steepest grade, and give its location; and also that it is perhaps ten feet or fifteen feet steeper than any other. He may say, also, that in each case the grade was made as small as possible, regardless of reduction of cost of road by allowing the grade to go up to the controlling maximum at any point on a portion to which this controlling maximum belongs.

Recently a number of the directors and officials of the Highland Railway Co. witnessed a series of experiments with the Westinghouse brake, over the Waverley route, for the purpose of satisfying themselves as to its efficiency, with a view to its adoption on the Highland lines. The train was composed of an engine, with 6 carriages and a guard's van; and the experiments consisted chiefly in pulling up while running at high rates of speed. The stoppage was repeatedly accomplished in distances of from 300 to 400 yards; on one occasion, in descending a gradient of 1 in 70, at the rate of 60 miles an hour, the train was brought to a stop within a distance of from 500 to 600 yards. Another test was the uncoupling of a part of the train while going at full speed, and the application of the brake. The result was that the latter portion was brought to a standstill almost immediately, while the front part was pulled up within less than 300 yards, notwithstanding that the steam was kept full on.

ON THE PROPER DIAMETER OF ELECTRIC CONDUCTORS.

By FREDERICK E. UPTON, U.S.N.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

It is proposed in the following paper to determine theoretically the proper diameter of electric conductors, regard being had (1) to their economy, and (2) to their adaptability to convey and distribute with uniformity electric energy to the various units of a system in which that energy is to be developed.

NOTATION.

Following is the notation which will be employed, certain values being assigned to some of the arbitrary constants for purpose of illustration:

a—A constant depending upon the material of the conductor (for copper about .000015.)

b—Price of material of conductor in cents per pound (for copper wire 35.)

C—Strength of current.

d—Diameter of conductor in inches.

h—Hours per day work is being performed (9.)

I—Interest on cost of conductor in cents per annum.

i—Yearly rate of interest in hundredths, (.10).

K—Cost of useless work developed in conductor in cents per annum.

k—In electric lighting, the estimated average proportion of lamps, in actual use during the time h, to the whole number of lamps in a system.

L—Length of conductor in feet.

l—Price of coal in cents per pound (.2).

M—$\frac{.0011735anhl}{sbi}$, (.000 000 09865).

N—Whole number of lamps or other units in a system.

n—Number of pounds of coal consumed in boiler per hour, for each horse-power of electrical energy developed in circuit (3.5).

P, p—Work in foot pounds per minute.

R, r—Resistance in ohms.

s—Weight of the material of conductor, in pounds to the cubic inch, (for copper wire .3212.)

DERIVATION OF THE FORMULA.

In any conductor

$$r=\frac{a\mathrm{L}}{d^2} \quad . \quad . \quad . \quad (1).$$

In a simple circuit the work developed in any part of it, during a given time, is proportional to the resistance of that part, whence

$$p=\mathrm{P}\frac{r}{\mathrm{R}}=\frac{a\mathrm{LP}}{\mathrm{R}d^2} \quad . \quad . \quad . \quad . \quad (2).$$

The capital letters refer to any object in the circuit in which useful work is to be developed, the small letters to the conductor.

$$\mathrm{K}=\frac{365pnhl}{33000}=\frac{.01106anhl\mathrm{PL}}{\mathrm{R}d^2} \quad . \quad . \quad . \quad (3).$$

$$\mathrm{I}=3\pi\mathrm{L}d^2sbi \quad . \quad . \quad . \quad (4).$$

Now if any infinitesimal increment, dd, positive or negative, be added to d, the resulting increments of K and I will be

$$d\mathrm{K}=-\frac{.0221anhl\mathrm{PL}}{\mathrm{R}d^3}\times dd \quad . \quad . \quad . \quad (5).$$

$$d\mathrm{I}=6\pi\mathrm{L}sbid\times dd \quad . \quad . \quad . \quad (6).$$

These expressions show what would be the increase or diminution of the cost of heating the conductor, and of the interest on the cost of the material of the conductor, resulting from an infinitesimal change in its diameter.

The negative sign of dK indicates that it progresses in a direction opposite to dd.

It is evident from inspection of (5) and (6) that a value may be assigned to d so large that the sign of $d\mathrm{K}+d\mathrm{I}$ will be the same as that of dI; also one so small that the sign of $d\mathrm{K}+d\mathrm{I}$ will be the same as that of dK; and, since dK and dI have contrary signs, there must be some value of d which will render

$$d\mathrm{K}+d\mathrm{I}=0 \quad . \quad . \quad . \quad (7).$$

Let that value be d'; if a positive increment is now applied to d', (7) will have the sign of dI which is the same as that of dd', that is, increasing or $+$; or if a negative increment be applied to d', (7) will have the sign of dK, that is, contrary to dd' or still $+$. Hence when $dK + dI = 0$, any increase or diminution of d' will result always in an increase of $dK + dI$, and the most economical diameter is thus determined.

Integrating (7)

$$K = I \quad . \quad . \quad . \quad . \quad . \quad (8).$$

numerically. Whence

$$d'^2 = \sqrt{\frac{MP}{R}} = \sqrt{44.236M}\, C \quad . \quad . \quad . \quad (9).$$

L has disappeared, which shows that the most economical size of conductor is independent of its length.

Formula (9) gives correct results for insulated wire, if b is made to equal the price of the material of the conductor per pound, plus the price of the insulation covering a pound, when that is constant for the different sizes. It also may be readily adapted to any other source of energy than coal.

APPLICATION OF THE FORMULA TO ELECTRIC LIGHTING.

Let p_1 be the foot pounds of work per minute required for one light, at a standard brilliancy, r_1, the resistance of one light.

I. In a *simple* circuit, where the lights are connected in series, $R = kNr_1$, $P = kNp_1$. Hence

$$d_s'^2 = \sqrt{\frac{Mp_1}{r_1}} \quad . \quad . \quad . \quad . \quad . \quad (A).$$

Or, in a simple circuit, d'_s is independent of the number of lamps, and depends solely upon the elements of a single lamp, as might have been inferred from the disappearance of L referred to above.

II. In a *multiple* circuit, neglecting the conductors, $R = \frac{r_1}{kN}$, $P = kNp_1$; let the unknown resistance of the conductors be the q part of $\frac{r_1}{kN}$; then $R = \frac{r_1}{kN}(q+1)$. As the work developed in a circuit, increases in the same proportion as the resistance (C being constant), $P = kNp_1(q+1)$, and (9) becomes

$$d'^2_m = kN\sqrt{\frac{Mp_1}{r_1}} \quad . \quad . \quad . \quad (B).$$

Or, in a multiple circuit, d'_m is independent of the lengths of the conductors or any of them, and depends on the elements of a single lamp and the number of lamps.

For any description of lamp, d'^2_m and the gauge number may be tabulated for kN.

III. If, however, in a multiple circuit, the sizes of conductors are calculated by (B), the different lights of a system will not be of uniform brilliancy, unless they are all at the same distance from the generator following the route of the current. Otherwise, those nearest the generator will be the brightest.

Consider a circuit divided into two circuits, numbered 1 and 2, and containig m and n lamps respectively; the conductors to which these lamps are attached will be called the connecting wires, and the lamps are supposed to be attached to them in multiple circuit without any other resistance than that of the lamps themselves, that is, $\frac{r_1}{m}, \frac{r_1}{n}$. Then by (B), $d_1'^2 : d_2'^2 :: m : n$, or the current and work will divide correctly if the resistance of the connecting wires be neglected, and enter each circuit according to the number of lights to be supplied. But the connecting wires have resistances, which should manifestly be in the same ratio as that of the lamps in circuits 1 and 2, in order for the work still to be distributed correctly; that is, we must have

$$r_1 : r_2 :: \frac{1}{m} : \frac{1}{n} :: \frac{1}{d_1'^2} : \frac{1}{d_2'^2}$$

But from (1)

$$r_1 : r_2 :: \frac{L_1}{d_1'^2} : \frac{L_2}{d_2'^2}$$

In order for the first proportion to obtain, L_1 must equal L_2, which is the condition of uniform brilliancy. The same is true of any number of parallel circuits; the connecting wires must be of such length as to bring all the lamps to the same distance from the generator.

In practice the lengths of the connecting wires are determined by local circumstances, and, therefore, they will not generally have the proper resistance for uniform distribution of work. It will, hence, be necessary to modify their computed diameters.

Let some constant distance, L′, be assumed, to which the distances of all the lamps from the generator must be made equivalent as regards resistance. Designate the actual length of the connecting wire by L, and the length it should have to bring the lamp to the distance L′ from the generator byD. Then there will result for *connecting wires* only

$$d'^{2}_{cm} = kN\sqrt{\frac{Mp_1}{r_1}}\frac{L}{D} = d'^{2}_{m}\frac{L}{D} \quad . \; . \; . \; (C).$$

L′ must be at least nearly equal to the distance of the farthest lamp from the generator, always following the route of the current.

All the conductors, except the connecting wires, are given by (B). The turning on or off of any number of lamps will not affect the uniformity of the brightness of the rest.

The system as thus arranged may be replaced, for most purposes of computation, by an equivalent system, consisting of kN lamps arranged like a chandelier, connected with the generator by a conductor whose length is L′ and whose diameter is given by (B).

Applying the formula (B) to find the size of the main conductor, leading from the generator to the first derivation, to supply 1200 lamps of Edison's pattern, where $p_1 = 3000$, $r_1 = 130$, assigning to M the value previously given under the head of Notation and to k .5, then there results, $d'_m = .95$ inches. This is also the diameter of the conductor of the theoretical system just referred to.

GENERAL APPLICATION.

Formulæ (B) and (C) may be used to determine the proper size of conductors in all cases where economy would be a matter of importance, such as the storage of electricity at a distance, or the transmission of power to any number of secondary electric machines. The formulæ will then take the general form:

$$d'^{2} = \frac{N}{Q}\sqrt{\frac{Mp_1}{r_1}} \quad . \; . \; . \; (D).$$

Where Q is the number of cells, machines, &c., connected end on in each series, and $\frac{N}{Q}$ is the number of of series. The arrangement in any particular case depends on the ratio of the elements of the generator to those of a single unit of the receiving system.

ON THE STRENGTH OF WROUGHT-IRON BRIDGE MEMBERS; INCLUDING STRUTS, COLUMNS, SEMI-COLUMNS, BEAMS, &c.

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Written to accompany Report to the Hon. H. SABINE, Commissioner of Railroads and Telegraphs.

I.

The examination of bridges for strength and trustworthiness has occasioned the use of formulas not accessible to the writer in published form. In procuring the formulas by direct solution, the amount of labor entailed has been great. The avoidance of a repetition of this labor on the part of others who may require these formulas, is believed to be sufficient reason for now publishing the results obtained.

To make clear the nature of the formulas required, the conditions to which certain bridge members are subject may be referred to. Thus, in some instances, the chords of truss bridges are required to carry the floor beams, one, two or more of them, to each panel. Now, when a train of cars comes upon a bridge, the floor-beam loads rest down upon the chord members and deflect them into downward bowing curves, causing "transverse strains," or "bending moments." Simultaneously, the load upon the bridge causes endlong strains in the same chord members; tension for the lower, and compression for the upper chord. Thus, an individual member of the chord of the bridge, such as an "eye bar," is to be treated as a beam subjected to a combined bending and stretch, or bending and compression, as the case may be.

The usual way of calculating the resulting maximum strain in the piece considered, is to compute as though the beam had only the "cross strain," and then compute separately for the endlong strain, and add the results. It is evident, however, from a casual consideration that as the bending load would separately give a certain curve to the beam, the tension would partially straighten that curve and diminish the bending moment. Again, in a compressive endlong strain, the curvature of the beam would be increased and the bending moment increased. Hence, the usual calculation would give too large a value to the maximum strain per square inch in one case, and too small in the other. The formulas given in this article correct these anomalies.

The conditions of the piece just referred to as regards loading and supports are stated in general terms, but it is evident that they include all such special conditions as concentrated loads; distributed loads; one end fixed and the other free; one end fixed and the other supported; both ends supported; both ends fixed, &c.

TRUE FLEXURAL MOMENT AND ITS RESISTANCE IN MIXED STRAINS.

Before proceeding to special cases, it is necessary to consider the pseudo-philosophy of eccentric neutral axis in beams subject to both endlong and cross forces.

For the sake of fixing the ideas, let Fig. 1 represent a beam fixed at the end, B, and free at the end, A. Let the cross force, P, act at right angles to the beam, and the endlong force, T, in the direction of the length, both being applied at the free end of the beam. The bending will be as shown, the fibers on the upper side of the beam being stretched, and those on the lower side being compressed, if T is not too great.

Now, undoubtedly one effect of T is to elongate the whole beam and every part of it, throwing the neutral axis for all the stresses, downward from the line ACB to some line C′B′, or C″B″ This displacement is proportional to $\frac{T}{Px}$ for the section at the distance x, from the free end of the beam. If $T=o$, the displacement $=o$, anywhere. If $P=o$, the displacement is ∞, anywhere. If $x=o$, the displacement $=\infty$. If $x=l$, and P very small, the displacement is very great. But for T and P moderate, the displacement is moderate. For T and P constant and x variable, the departure of the line of the neutral axis, C′B′ from CB, increases as x decreases, and, geometrically speaking, it is asymptotic to the horizontal through B, and to the vertical, through A. Though this line is a real *neutral* axis, as regards stress, it can easily be shown that it is not the most convenient line in which to place the origin of moments, for the well known differential equation of the elastic curve, viz.:

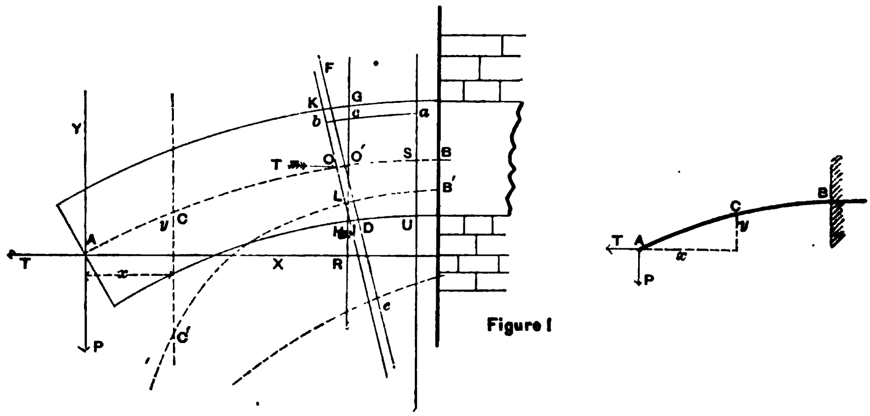


Figure 1

$$\varepsilon I \frac{d^2 y}{dx^2} = \Sigma P x = \Sigma(\text{applied moments}),$$

$$= M \quad . \quad . \quad (1)$$

This equation, as it stands, is an equation of moments of forces, the second member being the sum of the moments of the forces acting on the beam, while the 1st member is the sum of the moments of the internal forces of the beam resisting bending, or, more briefly, the "moment of resistance" of the beam. The origin of moments, or moment axis for this equation, is taken on some certain cross section of the beam, as, for instance, DF, and then the moments of the forces are to be expressed for that particular origin of moments. The equation is then integrated, resulting in the equation of the elastic curve. The effect of the integration is to move the plane, D F, from end to end of beam, thus summing the bending effects due to each element of length of beam.

That the origin of moments for the above equation of moments should be taken on the sectional plane, DF considered, no one doubts; but *where* it should be taken is seriously questioned. Some writers definitely locate it, by saying that the moment of inertia, I, is here variable, the neutral axis not being parallel to the beam. According to this, if C′B′ be the neutral axis, as above described, the origin of moments must be taken at L, in applying the above general equation (1) to Fig. 1. The moment of inertia, I, of the section, DF, is then to be expressed for the moment of inertia axis at L, coinciding with the origin of moments. Now, to discuss this conclusion, draw G H, DF, and JK, as shown. Let the portion, SO, of the beam be supposed to stretch, displacing DF to JK, this stretch being due to T. Again, let the bending moments displace GH, through an angle to FD, causing a stretch in the upper fibers and a compression in the lower fibers of the beam, the triangles, O′FG and O′HD, representing the two actions respectively. Respecting a fiber, *ab*, the stretch from the line, G, to F is due to cross strain, and from F to K, to endlong strain.

Now, for the sake of an argument, let it be granted that the origin of moments for equation (1) be taken on the real neutral axis, C′B′, at L. This point is where the cross section, JK considered, intersects the real neutral axis. That is, L is the point in the section, J K, where there is actually no longitudinal stress. The figure indicates this, since at the top of the beam, GF stands for stretch due to cross strain; FK, the stretch for endlong strain, their sum, GK, being the total stretch or stress. This stress is less and less in going down from the top, until it vanishes at L, where the limiting lines, GL and KL, for the stress named, intersect on the neutral axis, C′B′.

Now, in applying equation (1) to the beam, Fig. 1, with the understanding that the *origin of moments be taken at* L, we have

$$\frac{\varepsilon I}{\rho} = \varepsilon I \frac{d^2 y}{dx^2} = P.AR - T.RL \quad . \quad . \quad (2).$$

where the moment of inertia, I, of the first member, is to be so expressed that its axis coincides in position with the origin of moments, L. Let the beam be regarded as uniform in cross section from end to end, with the line, ACOB traversing the center of gravity of any cross section. Let I_1 represent the moment of inertia of the cross section considered, for an axis located at the center of gravity of that section. For KJ this axis is at O, the point *o* being the "principal axis" or "center of inertia." Now, a well-known principle in mechanics, by which I may be obtained from I_1, gives

$$I = I_1 + \text{section JK}.\overline{LO}^2 \quad . \quad (3).$$

Hence the first member of equation (2) is

$$\frac{\varepsilon I}{\rho} = \frac{\varepsilon I_1}{\rho} + \frac{\varepsilon}{\rho} \text{ section JK}.\overline{LO}^2$$

$$= \frac{\varepsilon I_1}{\rho} + \frac{\varepsilon}{\rho} K.\overline{LO}^2 \quad . \quad . \quad (4).$$

where K is here taken for the cross section JK.

The denominator ρ is the radius of curvature of the curve of the neutral axis as shown in Fig. 1.

If S U and G H be taken parallel before flexure and fixed to the beam, SO being regarded as an element of length, *dx*, of the beam, then during flexure S U and G H intersect at the center of curvature of the elastic curve, thus determining ρ. Then, relative to the fiber S O′ O, Fig. 1, we will have the stretch of the fiber=O′ O; and from the similarity of triangles we may write

$$OL : \rho :: O'O : SO.$$

$$\therefore \quad \frac{LO}{\rho} = \frac{O'O}{SO}$$

A well-known fundamental formula in the theory of the elastic resistance of beams is

$$T\,l = \varepsilon\,K\,d\,l \quad . \quad . \quad . \quad (4\tfrac{1}{2}).$$

where T is a force applied to a bar of length, l, of section K, and co-efficient of elasticity, ε; for which the stretch is $d\,l$. This formula may be applied to the part S O′ of the beam Fig. 1 by making l= S O′ and $d\,l$=O′ O, the section, K, being the same whole section, J C. In this, the dl is=O′ O=F K=D J.

Hence

$$T.SO' = \varepsilon K.O'O = \varepsilon K.\frac{LO}{\rho}.SO$$

or

$$T = \varepsilon K \frac{LO}{\rho}$$

combining this with (4), we get

$$\frac{\varepsilon I}{\rho} = \frac{\varepsilon I_1}{\rho} + T.LO$$

Comparing with equation (2) we have

$$\frac{\varepsilon I}{\rho} = \frac{\varepsilon I_1}{\rho} + T.LO = P.AR - T.RL$$

or

$$\frac{\varepsilon I_1}{\rho} = P.AR - T.RL - T.LO$$

$$= P.AR - T\,(RL + LO)$$

or

$$\frac{\varepsilon I_1}{\rho} = \varepsilon I_1 \frac{d^2 y}{dx^2} = P.AR - T.RO. = M$$

$$= \Sigma Px - \Sigma Ty \quad . \quad . \quad (5).$$

This equation has for its first member the ordinary expression for the moment of elastic resistance of beams, subject simply to bending forces applied only at right angles to the beam; that is to say, the expression in which the origin of moments for the resisting forces is at the center of gravity of the cross section of beam considered, or at O, Fig. 1. The second member expresses simply the moments of the applied forces for the same origin of moments, viz.: the point O.*

Hence it follows that in cases of flexure of beams, where part of the forces are applied in an endlong or longitudinal direction, the moments may unhesitatingly be expressed with reference to an origin of moments located at the center of gravity of the cross section considered. Equation (5) makes this evident, not only for the moment of resistance but for the entire number of the applied forces. Indeed, a little consideration of M, in equation (5), shows that the above statement respecting the moment of the applied forces is true in general; that is to say, it is true for any number of forces, having any conceivable points of application, and having any conceivable lines of direction. For each force may be resolved into two components, one longitudual and the other transverse; T.RO being the algebraic sum of the moments of all the former and P.AR of the latter. It is to be understood that in the integrations, proper limits are to be chosen, so that no point of concentration of applied force be overstepped in this, any more than in ordinary problems.

These facts place all problems in the resistance of beams on the same basis, that is to say, equation (5) applies with equal truth and exactness for a beam subject to the action of any system of forces, however complex, as for the simple case of a single transverse force; I_1 being always regarded as the principal moment of inertia and constant for a beam of uniform cross section.

This complete generalization of equations (1) and (5) for a constant value of I is important, since the integrations are not only facilitated, but we are enabled to apply the resulting formulas for a beam under any system of forces, with the same degree of confidence as for the most simple case.

To confirm the facts above stated by discussion, let us refer to Fig. 1. First,

* In the above transformation the radius of curvature ρ has been all the time regarded as of the same value. Fig, 1 shows that this is correct. For in $\frac{\varepsilon I}{\rho}$ it extends from L to the center of curvature, or to where L J produced meets SU produced. In $\frac{\varepsilon I_1}{\rho}$ it extends from O′ to where O′D intersects SU produced. But as LJ and O′D are parallel to each other the radii of curvature have the same value.

suppose P applied, bending the beam downward as shown. Then apply T as shown. This latter will evidently partially straighten the curvature, and raise the end of the beam. But it will finally come to rest under some degree of curvature, P and T both acting. The portion S O′ of the beam will stretch, D F moving to J K. Next apply an equal and opposite endlong force—T, at the center of gravity O, of the cross-section J K. This latter will have no tendency whatever to bend the portion S O, but it will exactly return J K to D F. In this the end of the beam will not be raised or lowered, the deflection being entirely due to the two forces acting at the end of the beam. The stress in the beam is now simply that represented by the triangles O′ G F and O′ D H. The moment of resistance is $\frac{\varepsilon I_1}{\rho}$ axis for I_1 being at O′, and the moment of P will be P.AR. But as to T we have a *couple* between T at the line AR and—T at O′ the arm of the couple being RO. Hence the moment of this couple is T.RO′. All these moments are seen to have the origin of moments at the point O, or O′ both being practically the same point. This re establishes equation (5).

So far, the endlong force, when spoken of in connection with Fig. 1, has been treated as producing tension. But it is easily seen that similar reasoning follows for T, so taken as to compress the beam. Indeed, the algebraic sum, T.OR, mentioned above, contemplated positive as well as negative forces.

Equation (5) enables us to find the equation of the elastic curve of the bent beam. Having the equation of the curve, we can readily find the deflection at any point. Also the moment of strain M, may be found as soon as the unknown constants of integration are determined.

TRUE MAXIMUM STRAIN IN ANY CROSS SECTION.

By aid of the moment M and the endlong force T, we may find the maximum strain produced in any cross section of the beam, as for instance in the section at O, Fig. 1. At the top of the beam, the strain is GK, and at the bottom it is JH; GK being the greater, it is the one sought.

The strain GK is the sum of two parts, GF and FK, the former being due to the moment M of bending, and the latter to the direct tension T. To find the total amount of this strain per square inch, we may apply the well known formula for the strength of beams for finding the part GF thus

$$\frac{t_1 I_1}{d_1} = M, \quad . \quad . \quad . \quad . \quad (6).$$

where M is given by equation (5), as the algebraic sum of the moments of all the applied forces, the center of gravity of the section considered being the origin of moments, I_1 the *principal* moment of inertia for the same section, as previously stated, d_1 the distance from the center of gravity of the section to that point where the strain is greatest, and t_1 is the strain due to the moment M. In Fig. 1 O′ is the center of gravity of the section DF considered, I_1 is the moment of inertia of that section for O′ the axis, and d_1 is O′F. As a formula for determining the moment of ultimate resistance of beams, t_1 is to be assumed equal the ultimate resistance or modulus of resistance to rupture. Equation (6) is the converse of this, where M is predetermined and t_1 found as a stress considerably below the ultimate value. In calculating the ultimate strength of beams, formula (6) is known to give values wide of the truth. This is due to the fact that the law of resistance in the neighborhood of rupture deviates greatly from the law of perfect elasticity. But within the elastic limits, as will usually be the case with (6), the formula, as is well known, will be truthful. The strain FK Fig. 1, as above explained is due to T, and if the intensity be represented by t_2 and the sectional area DF by K, we will evidently have

$$t_2 K = T \quad . \quad . \quad . \quad . \quad (7)$$

Let t_1=GK, Fig. 1, stand for the whole maximum strain per square inch in the section considered.

Then

$$t = t_1 + t_2 = \frac{Md_1}{I_1} + \frac{T}{K} \quad . \quad . \quad . \quad (8).$$

a perfectly general formula, free from all assumed approximations except in the instance where ρ is placed equal the second differential co-efficient. This, however, is done by all writers on beams. But it is known that the error in this assumption is of no practical import whatever in beams as ordinarily used. It is zero where the bent beam is not inclined to the axis x, and for an inclina- of 10° it is less than 5 per cent.

It is to be observed that for rupturing strains d_1 is to be taken as the distance from the center of gravity of the section to the point where the rupture takes place, whether it be by tension or compression.

When the beam is rectangular in cross section with a breadth b and depth d, we have

$$d_1=\frac{d}{2},\ I_1=\frac{bd^3}{12},\ \text{and } K=bd,$$

and hence (8) becomes,

$$t=\frac{6M}{bd^2}+\frac{T}{bd} \quad . \quad . \quad . \quad (9).$$

Here d_1 disappears, as indeed it will in all cases where the cross section of the beam is symmetrical with respect to an axis to that section taken horizontal through O′ Fig. 1.

NEUTRALIZING OF MOMENTS DUE TO CROSS STRAINS.

It is often desirable to so assume the point of application of T, as to place the beam under the least possible maximum stress when the structure containing the the beam receives its maximum load. For instance, suppose the lower chord of a bridge carries the floor beams, several to each panel. Then it is evident that T may be applied at such point as to make its moment, with respect to the section of beam in question, equal and opposite to the moment of P. This makes M = 0, and consequently $t_1=0$. This is evidently the best condition, since t_2 and T are sole and mutual dependencies, and, at best, the minimum strain can never fall below t_2. This, and also equation (8) agree in making $t_1=0$ and hence, for minimum strains,

$$M=o, \text{ and } t_1=o.$$

To illustrate further, take an "eye bar" of a lower chord of any bridge. Let ABCD represent the loads due to floor beams. The section at the middle of the length will receive the greatest moment of strain due to ABC, &c., while the tension T is uniform throughout. Now, that $t_1=o$, the centers of the eyes must be raised a distance ab, shown at the middle section, so that for the maximum bridge load,

$$T.ab=\begin{cases}\text{sum of the moments of AB and}\\ \text{P, with respect to } a \quad . \quad . \ (10).\end{cases}$$

When this condition is exactly satisfied, the middle part of the beam near

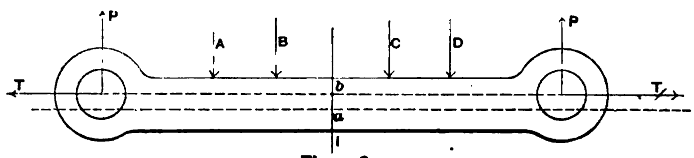


Figure 2.

JK will be simply stretched and not sprung into curvature. But if the body of the bar be straight when free from strain, it will, when under the condition, (10) be sprung at points near the eyes. The problem then becomes complex because ab varies with the spring, and would require to be determined with due regard to the amount of flexure, as subsequently done in this article.

But it is possible to so curve the bar in the manufacture, that any part of it will be simply stretched when bearing its maximum load. To indicate a few of the simpler forms, suppose only a single floor beam at the middle of the bar at K. Then the center line of the bar should be a straight line from a, Fig. 2, each way, to the centers of the eyes, the distance ab being formed by (10). If there were two floor beams on the link, say A and D only, then the link should be straight between A and D, and also between these points and the centers of the eyes, the lines from point to point being constantly at mid-depth of the body of the bar. If the floor beams were so numerous as to be treated as constituting a uniformly distributed load, the curve of the center line of the body of the link would be a parabola running from center to center of eyes, with vertex at a, and with the principal axis vertical. Equation (10) would still determine ab, the 2d member being regarded as the sum of the movements of all forces except T. For this case the equation would take the form,

$$T.ab=P\frac{l}{2}-\frac{wl^2}{8} \text{ for the middle point,}$$

and (11).

$$Ty=Px-\frac{wx^2}{2} \text{ for any point,}$$

the origin of co-ordinates being at the middle of one eye, with l the length of the bar, and w the loading per unit length.

In cases where the cross section of the beam is non-symmetrical, as often the case in upper chords of bridges, the center of gravity of that section is to be found and then ab laid off, downward in the upper chord and upward in the lower chord.

When chord members are very long, the moment due to their own weight should be found and ab determined by (11).

GENERAL INTEGRALS FOR SOLVING CASES OF MIXED STRAINS.

In the designing of new structures the precautions pointed out above relative to maximum stresses in mixed strains may be provided for in the simplest way, viz: by computing separately and adding, though this may not always be preferable. When this approximate method is not desirable, and in cases where existing structures are to be examined, it may become necessary to make a careful determination of the moment M. To meet this requirement the various cases following have been worked out.

Before taking up the special cases an examination of the expressions for the moments of applied forces, shows that the integrations all come under two general forms, and it will be seen to be decidedly preferable to perform the two integrations once for all than to integrate for each special case.

The first general form is

$$\frac{d^2y}{dx^2}=Ay+Bx+Dx^2+F \quad . \ (12).$$

Differentiate twice, and

$$\frac{d^4y}{dx^4}=A\frac{d^2y}{dx^2}+2D.$$

Now put

$$\frac{d^2y}{dx^2}=n,$$

and differentiate twice,

$$\frac{d^4y}{dx^4}=\frac{d^2n}{dx^2}=A\frac{d^2y}{dx^2}+2D$$

or

$$\frac{d^2n}{dx^2}=An+2D$$

multiply through by dn, and integrate, and we get

$$\frac{dn^2}{dx^2}=An^2+4Dn+C$$

or

$$dx=\frac{dn}{\sqrt{A}\sqrt{n^2+\frac{4Dn}{A}+\frac{C}{A}}}$$

whence, by integration

$$x=\frac{1}{\sqrt{A}}\text{hyp. log}\frac{\frac{2D}{A}+n+\sqrt{n^2+\frac{4Dn}{A}+\frac{C}{A}}}{C_1}$$

Passing to exponentials and transposing in part,

$$C_1e^{x\sqrt{A}}-\frac{2D}{A}-n=\sqrt{n^2+\frac{4Dn}{A}+\frac{C}{A}}$$

By squaring both members and canceling

$$C_1^2e^{2x\sqrt{A}}-\frac{4D}{A}C_1-e^{x\sqrt{A}}-2C_1ne^{x\sqrt{A}}+\frac{4D^2}{A^2}=\frac{C}{A}$$

solving for n we obtain

$$\left.\begin{aligned}n&=\frac{C_1}{2}e^{x\sqrt{A}}-\frac{C}{2C_1A}e^{-x\sqrt{A}}\\&\quad-\frac{2D}{A}+\frac{2D^2}{C_1A^2}e^{-x\sqrt{A}}\\&=\frac{d^2y}{dx^2}=Ay+Bx+Dx^2+F\end{aligned}\right\}(13)$$

The second general form is

$$\frac{d^2y}{dx_2}=-Ay-Bx-Dx^2-F \ . \ . \ (14).$$

Differentiate twice and

$$\frac{d^4y}{dx^4}=-A\frac{d^2y}{dx^2}-2D$$

Put

$$\frac{d^2y}{dx^2}=+n$$

and differentiate twice

$$\frac{d^4y}{dx^4}=\frac{d^2n}{dx^2}=-A\frac{d^2y}{dx^2}-2D$$

or

$$\frac{d^2n}{dx^2}=-An-2D$$

Multiply through by dn and integrate and

$$\frac{dn^2}{dx^2}=-An^2-4Dn+C'$$

or

$$dx=\frac{dn}{\sqrt{C'-4Dn-An^2}}$$

But

$$\int\frac{dz}{\sqrt{a\pm bz-cz^2}}=\frac{1}{\sqrt{c}}\sin^{-1}\frac{2cz\mp b}{\sqrt{4ac+b^2}}$$

where $a=C'$, $b=4D$, $c=A$, $z=n$.

Hence

$$x=\frac{1}{\sqrt{A}}\sin^{-1}\frac{2An+4D}{\sqrt{4AC'+16D^2}}-C'_1$$

or

$$\sin(x\sqrt{A}+C_1')=\frac{An+2D}{\sqrt{AC'+4D^2}}$$

Solving for n, we obtain

$$\left.\begin{array}{l} n=\frac{\sqrt{AC'+4D^2}}{A}\sin(x\sqrt{A}+C_1') \\ -\frac{2D}{A}=\frac{d^2y}{dx^2}=-Ay-Bx-Dx^2-F \end{array}\right\} (15).$$

In the application of (13) and (15) to the following cases, it is only necessary to cut out any redundant term, and determine the constants of integration.

SOME OF THE PRINCIPAL CASES UNDER MIXED STRAINS.

I. *For the first case let the beam be fixed at one end, free at the other, and having a load P and pull T applied at the free end.* Fig. 1 or 1a represents it. The first question arising is whether to apply (13) or (15). An inquiry will reveal the fact that the sign of Ty determines which. The calculus demands that the ordinate and second differential coefficient have contrary signs when the curve is concave toward the axis of x. Hence in Fig. 1 they are contrary. Taking T positive when it is directed toward the beam, and negative when from it, we

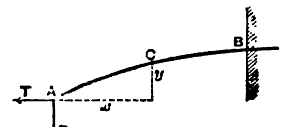


Figure la

will have, for T pointing outward as in Fig 1 or 1a.

$$-\epsilon I_1\frac{d^2y}{dx^2}=Px-Ty=M$$

T being negative makes the sign of $\frac{d^2y}{dx^2}$ and Ty alike.

For convenience let the subscript to I be dropped in the following equations, I being always regarded as the principal moment of inertia of the cross section of the beam. Then we have for the origin of moments at C, Fig. 1a, and of coordinates at A,

$$\epsilon I\frac{d^2y}{dx^2}=Ty-Px=M \quad . \; . \; . \; (16).$$

To integrate this equation, we require (13) because the signs of Ty and Ay are alike, also of the second differential coefficients.

Comparing with (13)

$$A=\frac{T}{\epsilon I}\quad B=-\frac{P}{\epsilon I}\quad D=o\quad F=o$$

Hence

$$\frac{d^2y}{dx^2}=Ay+Bx=\frac{C_1}{2}e^{nx}-\frac{C}{2C_1A}e^{-nx}$$

where for convenience $n=\sqrt{A}=\sqrt{\frac{T}{\epsilon I}}$

n here differing from the n used in the integrations for (13) and (15). This equation is given in *Strength of Materials*, by De Volson Wood, p. 300, 2d ed.

Let the length of the beam be l, and the distance of the point of application of T below the center of gravity of the end of the beam be h. Then if $x=o$ $y=h$, and

$$Ah=\frac{C_1}{2}-\frac{C}{2C_1A}$$

∴

$$\frac{C}{2C_1A}=\frac{C_1}{2}-Ah$$

and

$$Ay+Bx=\frac{C_1}{2}\left(e^{nx}-e^{-nx}\right)+Ahe^{-nx}$$

$$A\frac{dy}{dx}+B=\frac{C_1}{2}\left(e^{nx}+e^{-nx}\right)-Ahne^{-nx}$$

But

$$\frac{dy}{dx}=o \text{ for } x=l \text{ and}$$

$$B=\frac{C_1}{2}n\left(e^{nl}+e^{-nl}\right)-Ahne^{-nl}$$

The value of C_1 from this, introduced above, gives

$$Ay+Bx=\frac{\frac{B}{n}+Ahe^{-nl}}{e^{nl}+e^{-nl}}\left(e^{nx}-e^{-nx}\right)+Ahe^{-nx}$$

Restoring the values of A and B, we get

$$Ty-Px=-\left(\frac{P}{n}-The^{-nl}\right)\frac{e^{nx}-e^{-nx}}{e^{nl}+e^{-nl}}+The^{-nx}$$

$$=M \quad . \quad . \quad . \quad . \quad . \quad (17).$$

This equation expresses the relation between x and y for the equation of the curve of the axis of the beam, that is to say, of the curve AOB, Fig. 1 or 1a. The maximum deflection of the beam is y_1-h for $x=l$.

Also (17) is so arranged as to give the moment of the applied forces for any point, the first member being the same as (16).

If $x=o$ $y=h$ as it should.

The maximum moment of strain for the whole beam is evidently at the fixed end where $x=l$ and $y=y_1$. Hence, by reduction,

$$Ty_1-Pl=-\frac{\frac{P}{n}\left(e^{nl}-e^{-nl}\right)-2Th}{e^{nl}+e^{-nl}}$$

$$=M_{max}. \quad . \quad . \quad . \quad (18).$$

When $h=o$,

$$Ty_1-Pl=-\frac{P}{n}\left\{\frac{e^{nl}-e^{-nl}}{e^{nl}+e^{-nl}}\right\}=M_{max}. \quad (19).$$

with h restored and $P=o$

$$Ty_1=\frac{2Th}{e^{nl}+e^{-nl}} \quad . \quad . \quad . \quad . \quad . \quad (20).$$

Evidently the resultant of T and P might be substituted, and be considered as a single force acting obliquely. Conversely any single force acting obliquely at the end of the beam could be resolved into components corresponding with T and P.

If we imagine this resultant acting at the end of h, its prolongation would intersect the beam when h is downward. This point of intersection would evidently be a point of contrary flexure at which the moment would be zero. The point could be found by placing the 2d member of (17) $=o$ and solving for x. This point would be a neutral point for an S shaped curve,

II. *Let the conditions be as in* I, *except change T to a push.*

This would seem to be met by changing the sign of T, but this makes all the expressions in case I imaginary. But it may be rationalized as done in Prof. Wood's *Strength of Materials*, p. 301, 2d. ed. But if we change the sign of P instead of T, the relation of signs of T and P is right. In applying equation (19) with sign of P changed, we will obtain a negative result for y, while when P is positive y is positive. Hence the conditions for this supposition are as shown in Fig. 3, with no essential change. It is

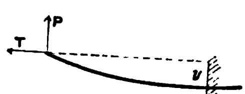


Figure 3.

simply case I turned over. The moment obtained from (19) is the same numerically for P + as for − which is evidently as it should be, while for T changed in sign it would be greater.

Hence, changing the sign of T, our equation of moments for this case becomes, as evident from Fig. 4, for the origin of moments at C and of co-ordinates at A.

$$\epsilon I\frac{d^2y}{dx^2}=-Ty-Px=M \quad . \quad . \quad . \quad (21)$$

This may be integrated by aid of equation (15), as the signs are proper to it, where,

$$A=\frac{T}{\varepsilon I}=n^2\quad B=\frac{P}{\varepsilon I}\quad D=o\quad F=o$$

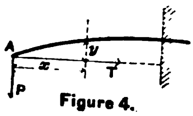


Figure 4.

Hence the integral is

$$-Ay-Bx=\sqrt{\frac{C}{A}}\sin(x\sqrt{A}+C_1)$$

$$=\sqrt{\frac{C}{A}}\sin\ (nx+C_1)$$

For $x=o$ let $y=h$ and

$$-Ah=\sqrt{\frac{C}{A}}\sin\ C_1$$

$$-Ay-Bx=-\frac{Ah}{\sin C_1}\sin(nx+C_1)$$

Differentiate and,

$$-A\frac{dy}{dx}-B=-\frac{Ahn}{\sin C_1}\cos(nx+C_1)$$

But

$$\frac{dy}{dx}=o\ \text{for}\ x=l$$

$$\therefore\quad B=Ahn(\cos nl\ \cot C_1-\sin nl)$$

or

$$\text{Cot}\ C_1=\frac{B}{Ahn\ \cos nl}+\text{tang}\ nl$$

Hence

$$-Ay-Bx=-\frac{B}{n}\frac{\sin nx}{\cos nl}$$

$$-Ah\,(1+\text{tang}\ nx\ \text{tang}\ nl)\cos nx$$

or, restoring the values of A, B and n, we get the general equation of the curve of the axis of the beam, also the moment at any point,

$$-Ty-Px=-\frac{P\sin nx}{n\cos nl}-$$

$$Th(1+\text{tang}nx\text{tang}nl)\cos nx=M\quad .\ (22).$$

The maximum moment of flexure occurs where $x=l$ and $y=y_1$, which is

$$-Ty_1-Pl=-\frac{P}{n}\text{tang}nl-\frac{Th}{\cos nl}=$$

$$M_{\cdot max}\quad .\ .\quad (23).$$

when $h=o$

$$-Ty_1-Pl=-\frac{P}{n}\text{tang}nl=M_{\cdot max}\quad .\ (24).$$

When h is restored, and $P=o$

$$-Ty_1=-\frac{Th}{\cos nl}=M_{\cdot}\quad .\ .\quad (25).$$

III. *Let the beam be conditioned as represented in Fig. 5, viz.: fixed at one end, free at the other, with a load* P *and a pull* T *at the free end, and a uniform load over its length.*

Let w = distributed load per unit length of beam.

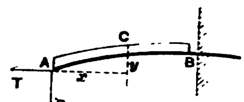


Figure 5.

Then the equation of moments will be

$$\varepsilon I\frac{d^2y}{dx^2}=Ty-Px-\frac{wx^2}{2}\quad .\ .\ .\quad (26).$$

Hence

$$+Ay+Bx+Dx^2=\frac{C_1}{2}e^{nx}-$$

$$\frac{Ce^{-nx}}{2C_1n^2}-\frac{2D}{n^2}+\frac{2D^2}{C_1n^4}e^{-nx}$$

where

$$A=\frac{T}{\varepsilon I}=n^2\quad B=-\frac{P}{\varepsilon I}\quad D=-\frac{w}{2\varepsilon I}$$

To determine the constants of integration make x and y zero for the point A. This gives

$$\frac{C}{2C_1n^2}=\frac{C_1}{2}-\frac{2D}{n2}+\frac{2D^2}{C_1n^4}$$

Introducing this, differentiating, and making $\frac{dy}{dx}=o$ for $x=l$ we get

$$\frac{C_1}{2}=\frac{B+2Dl+\frac{2D}{n}e^{-nl}}{\left(e^{nl}+e^{-nl}\right)n}$$

which introduced, gives us the following general equation of moments, and of the curve of the axis of the beam T, P and w being restored.

$$Ty-Px-\frac{wx^2}{2}=-\frac{P+wl+\frac{w}{n}e^{-nl}}{n}\left[\frac{e^{nx}-e^{-nx}}{e^{nl}+e^{-nl}}\right]+\frac{w}{n^2}\left(1-e^{-nx}\right) \quad . \; . \; . \; . \; (27).$$

In this equation the sign of P may be + or −; that is, P may act down or up. Under certain circumstances the beam will be S shaped, with a point of contra flexure, or of zero moment.

To ascertain this point place the second member $=o$ and solve for x.

The maximum moment is evidently obtained by making $x=l$. The equation then will reduce to

$$Ty_1-Pl-\frac{wl^2}{2}=-\frac{P+wl}{n}\left\{\frac{e^{nl}-e^{-nl}}{e^{nl}+e^{-nl}}\right\}+\frac{w}{n^2}\left\{1-\frac{2}{e^{nl}+e^{-nl}}\right\}=M_{max} \quad . \; (28).$$

If $w=o$ this equation reduces to (19), as it evidently should. Also P may be made zero, leaving simply the uniform load and T.

IV. *Let the condition be as in Fig. 5, except reverse* T, *as in Fig. 6.* Then

$$\epsilon I\frac{d^2y}{dx^2}=-Ty-Px-\frac{wx^2}{2} \quad . \; . \; (29).$$

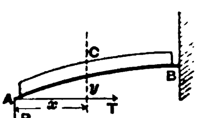


Figure 6.

Applying equation (15) for integrating this

$$-Ay-Bx-Dx^2=\frac{\sqrt{AC+4D^2}}{A}\sin(nx+C_1)-\frac{2D}{A}$$

where $A=\frac{T}{\epsilon I}$ $B=\frac{P}{\epsilon I}$ $D=\frac{w}{2\epsilon I}$

To determine the constants of integration make $x=o$ for $y=o$, and eliminate the coefficient to 1st term, 2d member. Then make the tangent to the curve zero for $x=l$, and eliminate C_1, as was done in case II., we then get

$$-Ty-Px-\frac{wx^2}{2}=-\frac{P+wl}{n}\frac{\sin nx}{\cos nl}-\frac{w}{n^2}(1-\cos.nx-\sin.nx\,\mathrm{tang}\,nl)=M \quad (30).$$

The load P may be + or −.

Making $x=l$ for the maximum moment, we get, by reduction,

$$-Ty_1-Pl-\frac{wl^2}{2}=-\left(\frac{P+wl}{n}-\frac{w}{n^2}\mathrm{tang}\frac{nl}{2}\right)\mathrm{tang}\,nl=M_{max} \quad . \; . \; (31).$$

If $w=o$, this expression reduces to (24), as it obviously should. If $P=o$ we have simply the uniform load w, and the end thrust T.

V. *Let the beam be supported at both ends, carry a uniformly distributed load, and have a pull applied at both ends.*

The conditions are obviously equivalent in the two parts of Fig. 7, the latter being already solved in equations (27) and (28).

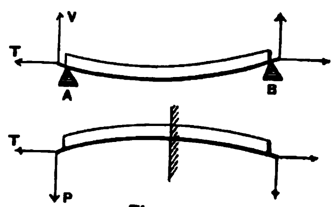


Figure 7.

The equation of moments for this figure is

$$\epsilon I\frac{d^2y}{dx^2}=Ty-\frac{wlx}{2}+\frac{wx^2}{2} \quad . \quad (32).$$

since $V=\frac{wl}{2}$. Comparing with (27) we find the 1st member changed to (32) by changing P, . $-w$ and l there, to $\frac{wl}{2}$ w and $\frac{l}{2}$ here. By making the corresponding changes in 2d member of (27) we obtain for the 2d member of (32)

$$+\frac{w}{n^2}\left\{\frac{e^{n\left(\frac{l}{2}-x\right)}+e^{-n\left(\frac{l}{2}-x\right)}}{e^{n\frac{l}{2}}+e^{-n\frac{l}{2}}}-1\right\} \quad (32).$$

l being the whole length, AB.

For the maximum moment $x=\frac{l}{2}$ and

$$Ty_1-\frac{wl^2}{8}=\frac{w}{n^2}\left\{\frac{2}{e^{n\frac{l}{2}}+e^{-n\frac{l}{2}}}-1\right\}.$$

M.max. . . . (33).

VI. *Reverse* T; *otherwise take the case as in* V.

Hence reverse w, and take $P=\frac{wl}{2}$ in equations (30) and (31) and change l to $\frac{l}{2}$ and we obtain

$$-Ty-\frac{wlx}{2}+\frac{wx^2}{2}=$$

$$\frac{w}{n^2}\left(1-\cos nx-\sin nx \,\text{tang}\, n\frac{l}{2}\right)=M \quad (34).$$

l being the whole length AB, and for the maximum moment $x=\frac{l}{2}$. ∴

$$\therefore\ -Ty_1-\frac{wl^2}{8}=-\frac{w}{n^2}\,\text{tang}\, n\frac{l}{4}\,\text{tang}\, n\frac{l}{2}$$

M.max . . . (35).

VII. *Let the beam be supported at its ends, with a load* Q *placed at equal distances from the ends, and have a tension* T *applied.*

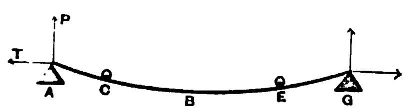


Figure 8.

1st. Then for the part AC, the moments will be

$$\epsilon I\frac{d^2y}{dx^2}=Ty-Px=Ty-Qx \quad . . (36).$$

comparing with eq. (13) we get

$$Ay+Bx=\frac{C_1}{2}e^{nx}-\frac{C}{2C_1A}e^{-nx} \quad . \ (13).$$

where

$$A=\frac{T}{\epsilon I}=n^2 \quad B=-\frac{P}{\epsilon I} \text{ and } P=Q \quad . \ (37).$$

For $x=o$, $y=o$ and

$$\frac{C}{2C_1A}=\frac{C_1}{2}$$

$$Ay+Bx=\frac{C_1}{2}\left(e^{nx}-e^{-nx}\right)$$

Differentiate and let $\frac{dy}{dx}=\text{tang}\ i$ for $x=a$ $=AC=EG$, and

$$\frac{C_1}{2}=\frac{A\,\text{tang}\,i+B}{\sqrt{A}\left(e^{na}+e^{-na}\right)}$$

$$\therefore\ Ay+Bx=\frac{A\,\text{tang}\,i+B}{\sqrt{A}}\left\{\frac{e^{nx}-e^{-nx}}{e^{na}+e^{-na}}\right\} \quad . . . . (39).$$

2d. For the part CB, the moments will be

$$\epsilon I\frac{d^2y}{dx^2}=Ty+Q(x-a)-Px=Ty-Qa$$

where

$$A=\frac{T}{\epsilon I}=n^2 \text{ and } F=-\frac{Qa}{\epsilon I} \quad . . (40).$$

$$\therefore\ Ay+F=\frac{C'}{2}e^{nx}-\frac{C_2}{2C'A}e^{-nx} \quad . . (13).$$

Now differentiate this and make $\frac{dy}{dx}=o$ for $x=\frac{l}{2}$ and

$$\frac{C_2}{2C'A}=-\frac{C'}{2}e^{nl}$$

Put this back in the same equation and make $\frac{dy}{dx}=\text{tang}\ i$ for $x=a$, and

$$A\,\text{tang}\,i=\frac{C'}{2}\left(e^{na}-e^{n(l-a)}\right)\sqrt{A}$$

This determines C' and C_2, and the values placed in the integral above give

$$Ay+F=\frac{A\,\text{tang}\,i}{\sqrt{A}}\left\{\frac{e^{nx}+e^{n(l-x)}}{e^{na}-e^{n(l-a)}}\right\} . \ (41).$$

Now making the ordinates y, in the two equations, equal each other for the point C, where $x=a$ we obtain observing that $Ba=F$, (39)=(41), giving an expression by aid of which tang i is found. This value of tang i, put into eq. (39) or (41), gives the required expressions for the moments on the parts AC and BC, respectively.

Placing the parenthetical part of (39) equal L, and of (41) equal N, we get

$$A\,\text{tang}\,i=-\frac{BL}{L-N} \quad . \ . \ (42).$$

The maximum moment on the whole beam will be found at the points C and E, directly under the equal loads Q, equidistant from the ends. This is obvious, from the fact that the moment due to P and Q for any part of CE is constant; but the moment of T, counter to that of P and Q, is least at C and E, for the part CE. As to AC, the moment is greatest at C.

Hence (39) or (41) will give the max. moment which is at $x=a$

$$\mathrm{T}y_1-\mathrm{Q}a=\frac{\mathrm{Q}}{2n} \cdot \frac{e^{n\frac{l}{2}}-e^{-n\frac{l}{2}}+e^{-n\left(\frac{l}{2}-2a\right)}-e^{n\left(\frac{l}{2}-2a\right)}}{e^{n\frac{l}{2}}+e^{-n\frac{l}{2}}}=\mathrm{M}_{\max} \quad (43).$$

If we make $a=o$ the moment (43) reduces to zero, as it evidently should, as it leaves the beam without load. Again, if $a=\frac{l}{2}$, the expression reduces to the same form as (19), P and l there, being equivalent to Q and $\frac{l}{2}$ here, a fact that verifies all complex and extended reductions of this case.

VIII. *Let this beam be conditioned the same as in* VII., *except reverse* T, *as shown in Fig. 9.*

The expression for the moment on AC is

$$\varepsilon\mathrm{I}\frac{d^2y}{dx_1}=-\mathrm{T}y-\mathrm{P}x,$$

where

$$\mathrm{A}=\frac{\mathrm{T}}{\varepsilon\mathrm{I}}=n^2 \qquad \mathrm{B}=\frac{\mathrm{P}}{\varepsilon\mathrm{I}}=\frac{\mathrm{Q}}{\varepsilon\mathrm{I}} \quad (44).$$

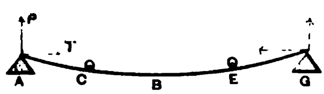


Figure 9.

Hence 1st by (15), making $x=o$ for $y=o$ for one constant, and $\frac{dy}{dx}=\text{tang}\,i$ at $x=a$ $=\mathrm{AC}=$ EG for the other constant.

$$-\mathrm{A}y-\mathrm{B}x=-(\sqrt{\mathrm{A}}\,\text{tang}\,i+\mathrm{B})\frac{\sin nx}{\cos na} \quad (45).$$

the eq. of the axis AC, and of moments for the same.

2d. For the part CB, moment=

$$\varepsilon\mathrm{I}\frac{d^2y}{dx^2}=-\mathrm{T}y-\mathrm{P}x+\mathrm{Q}(x-a)=-\mathrm{T}y-\mathrm{Q}a$$

where

$$\mathrm{A}=\frac{\mathrm{T}}{\varepsilon\mathrm{I}}=n, \quad \mathrm{F}=\frac{\mathrm{Q}a}{\varepsilon\mathrm{I}}=\frac{\mathrm{P}a}{\varepsilon\mathrm{I}}=\mathrm{B}a$$

Applying (15), first making $\frac{dy}{dx}=o$ for $x=\frac{l}{2}$ for one constant; then making the same equation $=\text{tang}\,i$ for $x=a$, for the other, we get

$$-\mathrm{A}y-\mathrm{F}=-\frac{\sin\left(nx+\frac{\pi}{2}-n\frac{l}{2}\right)}{\cos\left(na+\frac{\pi}{2}-n\frac{l}{2}\right)}\sqrt{\mathrm{A}}\,\text{tang}\,i \quad (46).$$

Then equating the ordinates y_1 from (45) and (46) for $x=a$, observing that $\mathrm{B}a=\mathrm{F}$, we get the expression containing tang. i. Substituting it in (46) we get the general expression of moments for the part CE, also the equation of the curve of the axis of that part,

$$-\mathrm{T}y-\mathrm{Q}a=-\frac{\mathrm{Q}}{n} \cdot \frac{\text{tang}\,na.\sin\left(nx+\frac{\pi}{2}-nl\right)}{\sin\left\{\frac{\pi}{2}-n\left(\frac{l}{2}-a\right)\right\}-\tan na.\cos\left\{\frac{\pi}{2}-n\left(\frac{l}{2}-a\right)\right\}}=\mathrm{M} \quad (47).$$

For $x=a$ this becomes

$$-\frac{\mathrm{Q}}{n}\cdot\frac{\text{tang}\,na}{1-\text{tang}\,na\cot\left\{\frac{\pi}{2}-n\left(\frac{l}{2}-a\right)\right\}}=\mathrm{M}_a \quad (48).$$

For $x=a=\frac{l}{2}$ we get

$$-\frac{\mathrm{Q}}{n}\text{tang}\,n\frac{l}{2}=\mathrm{M}_{\max} \quad (49).$$

(49) being greater than (48). This agrees with the indications of Fig. 9.

Equation (49) is the same as (24) as it evidently should.

If $a=o$ the moment reduces to zero, which the figure shows to be correct.

IX. *Let the beam be supported at the ends, be under tension T, and loaded with Q applied at any point.*

1st. For the part AC we get, origin of co-ordinates at A,

$$\epsilon I \frac{d^2y}{dx^2} = Ty - Px$$

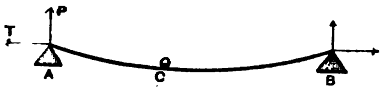


Figure 10.

Applying (13), observing that for $x=o$ $y=o$ for one constant: and that $\frac{dy}{dx}=$ tang i, for $x=a$ for the other, and reducing we get

$$Ty - Px = \frac{T.\text{tang}\, i - P}{n} \left\{ \frac{e^{nx} - e^{-nx}}{e^{na} + e^{-na}} \right\} \quad (50).$$

From the figure $Pl = Q(l-a)$

$$\therefore \quad P = Q\left(1 - \frac{a}{l}\right) \quad . \quad . \quad . \quad (51).$$

If in (50) we make $a = \frac{l}{2}$ we have tang $i=o$, and introducing P, (50) reduces to the same as (19) and (43) for like values of a, and P.

2d. For the part BC with some reduction,

$$\epsilon I \frac{d^2y}{dx^2} = Ty + \frac{Qa}{l}x - Qa$$

Applying (13) again, observing that for $x=l$ $y=o$, and $\frac{dy}{dx}=$ tang i, for $x=a$, and reducing we get

$$Ty + \frac{Qa}{l}x - Qa =$$

$$\frac{T.\text{tang}\, i + Q - P}{n} \left\{ \frac{e^{nx} - e^{n(2l-x)}}{e^{na} + e^{n(2l-a)}} \right\} \quad (52).$$

This equation reduces to the same as (50), (43) and (19) for like values of P, by making $a = \frac{l}{2}$; except (52) will have the negative sign, as it should, since its moment at C should oppose that of (50).

Now make $x=a$, and equate (50) and (52). This determines tang i. This can be restored to (50) and (52) for moments, or for equations of the curves of the axis of the parts of the beam. Thus the conditions of the beam are completely determined.

If we make the parenthetical part of (50) and (52) = L′ and N, respectively, we find, for $x=a$, in L and N,

$$\text{tang}\, i = \frac{Q}{n^2}\left(\frac{L}{L-N} - \frac{a}{l}\right) \quad . \quad . \quad (53).$$

For $a = \frac{l}{2}$; this reduces to o as it should.

In seeking the maximum moment we suspect that when Q is near A, or B at a particular point, the combined moment of T and P may possibly have a maximum between Q and the remote end, because that due to T varies as the ordinate y and P with x. But the mathematical test applied to (52) develops no such max. Hence the max. is always at the load Q, and can readily be found at $x=a$.

X. *Let the conditions be the same as in IX. except reverse* T, *or put the beam under compression, as in Fig. 11.*

Figure 11.

1st. For part AC

$$\epsilon I \frac{d^2y}{dx^2} = -Ty - Px$$

where

$$P = Q\frac{l-a}{l}$$

Integrating by aid of (15), making x and $y=o$ for one constant, and $\frac{dy}{dx}=$ tang i for the other, we obtain

$$-Ty - Px = -\frac{T\,\text{tang}\, i + P}{n} \frac{\sin nx}{\cos na} \quad . \quad (54).$$

2d. For the part BC we have

$$\epsilon I \frac{d^2y}{dx^2} = -Ty - (P-Q)x - Qa$$

Applying (15) and make $x=l$ for $y=o$ for one constant, and $\frac{dy}{dx}=$ tang i at $x=a$ for the other, and reducing we obtain

$$-\mathrm{T}y-(\mathrm{P}-\mathrm{Q})x-\mathrm{Q}a=\frac{\mathrm{T}\tan g\,i+\mathrm{P}-\mathrm{Q}}{n}\,\frac{\sin n(l-x)}{\cos n(l-a)}\quad .\ (55).$$

Equating 2d members of (54) and (55) for tang i at $x=a$, and then replacing it; the same equations become, for AC,

$$-\mathrm{T}y-\mathrm{P}x=\frac{\frac{\mathrm{Q}}{n}}{1+\tan g\,na\cot n(l-a)}\cdot\frac{\sin nx}{\cos na}\quad .\ (56),$$

and for BC,

$$-\mathrm{T}y-(\mathrm{P}-\mathrm{Q})x-\mathrm{Q}a=-\frac{\frac{\mathrm{Q}}{n}}{1+\tan g\,na\cot n(l-a)}\cdot\frac{\sin n(l-x)}{\cos n(l-a)}\quad (57).$$

which are equations of the axial curves and of moments.

These reduce to the same as (49) for $x=a=\frac{l}{2}$, also to (24) for proper value of l. Thus (56) becomes

$$\frac{\mathrm{Q}}{2n}\tan g\,n\frac{l}{2}=\mathrm{M}_{\max}\quad .\ .\ (58).$$

the same as (48), observing that Q in (48) equals 2Q in the above.

In looking for the max. moment, we observe that when Q is near A, the moment will without question increase from A to C, because the moment arms of both T and P increase together. Also the moment of the reaction of the support B will increase from B to C. But the moment of T is greatest where the curve of the axis of the beam is lowest, and this is between Q and B. Now when T is great and P small, particularly when T is sufficient to hold the beam in the curved form, the maximum is plainly seen to be somewhat removed from Q towards the middle of beam, but in no case beyond the middle.

The 2d member of equation (57) is the expression for the moment of flexure of BC. Hence the moment varies along BC as the ordinates of a sinusoid the max. value being where sin. $n(l-x)=1$, or where $n(l-x')=\frac{\pi}{2}$. Hence

$$\therefore\quad \frac{x'}{l}=1-\frac{\pi}{2nl}$$

is the fractional part of the beam's length at which the moment *may* be a maximum, and where it will exist, in case BC has a less value. At $x=l$, or at B, the sinusoid starts, and overspans the beam length AB, as appears from the fact that when $x=o$, the value of (57) is still considerable, and positive. To find the springing points of the curve, place

$$\sin n(l-x)=o$$

giving

$$n(l-x)=o \text{ or}=\pi$$

Hence

$$x=l,\text{ or}=l-\frac{\pi}{n}\quad .\ .\ .\ (59).$$

and the sinusoid is BED, for the beam AB, Fig. 12. The max. is at H when

$$\mathrm{AH}=l-\frac{\pi}{2n}\quad .\ .\ .\ (60).$$

equations (59) and (60) show that BD is twice BH. Suppose $n=.01$ and $l=200$. Then AH=43. and AD=−114.

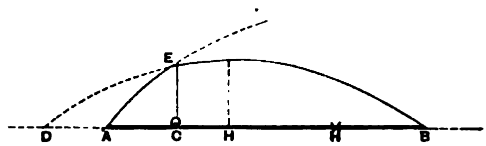


Figure 12.

The figure shows how the max. moment may occur at H when Q is at C, the curve AE being the sinusoid of eq. (56).

Similarly it may be shown that another point H′ exists where BH′=AH.

Now when Q is placed between H and H′, the max. moment is at Q, but it is at H or H′ when Q is outside those points.

XI. *Let the beam be fixed at one end, supported at the other, under compression T, and loaded with Q at any point.* Take the origin of co-ordinates at A, y positive downward and Ac=a. Then

1st for the part AC (Fig. 13)

$$\epsilon\mathrm{I}\frac{d^2y}{dx^2}=-\mathrm{T}y-\mathrm{P}(l-x)+\mathrm{Q}(a-x)$$

$$=-\mathrm{T}y-(\mathrm{Q}-\mathrm{P})x-(\mathrm{P}l-\mathrm{Q}a)$$

Integrating by aid of (15) we get

$$-\mathrm{A}y-\mathrm{B}x-\mathrm{F}=\frac{\sqrt{\mathrm{AC}}}{\mathrm{A}}\sin(nx-\mathrm{C}_1)$$

where

$$A=\frac{T}{\varepsilon I}=n^2 \quad B=\frac{Q-P}{\varepsilon I} \quad y=\frac{Pl-Qa}{\varepsilon I}$$

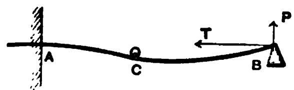


Figure 13.

For x and $y=o$ we get

$$\frac{\sqrt{C}}{n}=-\frac{F}{\sin C_1}$$

and for $\frac{dy}{dx}=o$ for $x=o$ we get

$$\cot C_1=\frac{B}{nF}$$

Hence

$$-Ay-Bx-F=-\frac{B}{n}\sin nx$$
$$-F\cos nx \quad . \quad (61).$$

and

$$-A \text{ tang } i-B=-B\cos nx+nF\sin nx$$

2d, For the part BC

$$\varepsilon I\frac{d^2y}{dx^2}=-Ty-P(l-x)$$
$$=-Ty+Px-Pl$$

Hence by (15)

$$-Ay-B'x-F'=\frac{\sqrt{C'}}{n}\sin(nx+C_1')$$

where

$$A=\frac{T}{\varepsilon I}=n^2,\ B'=-\frac{P}{\varepsilon I},\ F'=\frac{Pl}{\varepsilon I}$$

also

$$B'l+F'=o, B-B'=\frac{Q}{\varepsilon I} \quad a(B-B')=(F'-F)$$

For $x=l$, $y=o$ and

$$-B'l-F'=\frac{\sqrt{C'}}{n}\sin(nl+C_1')=o$$
$$\therefore \quad C_1'=-nl$$
$$\therefore -Ay-B'x-F'=\frac{\sqrt{C'}}{n}\sin n(x-l) \quad . \quad (62).$$

and

$$-A \text{ tang } i-B'=\sqrt{C'}\cos n(x-l)$$

Equating A tang i for $x=a$, from 1st and 2d and $\sqrt{C'}$ is determined, its value being

$$\sqrt{C'}=\frac{B-B'-B\cos na+nF\sin na}{\cos n(a-l)}$$

But in the present case P is as yet an unknown quantity, from the fact that Q is partly supported by the stiffness of the beam at A, and partly at B. We may, however, eliminate P by aid of the condition that the ordinates y from 1st and 2d are equal at $x=a$.

Equating the ordinates y, we find, after much reduction,

$$\frac{P}{Q}=\frac{\sin n(l-a)+na\cos nl-\sin nl}{nl\cos nl-\sin nl}=q$$

or $P=Qq$. . . . (63).

If $a=l$, $P=Q$; and if $a=o$, $P=o$; which are obviously correct.

The equation of the curve of the axis of the beam for AC, also the moment of flexure, will be

$$-Ty-Q\Big(q(l-x)-(a-x)\Big)=$$
$$-Q\Big((ql-a)\cos nx-\frac{q-1}{n}\sin nx\Big) \quad (64).$$

Similarly we have for BC

$$-Ty-Qq(l-x)=$$
$$-\frac{Q}{n}\Big(1-(1-q)\cos na+n(ql-a)\sin na\Big)$$
$$\frac{\sin n(l-x)}{\cos n(l-a)} \quad . \quad . \quad . \quad (65).$$

An inspection of the figure shows that there will always be a point of contra flexure in the beam, or where the moment of flexure will be zero.

Trying (64) for this point, placing the 2d number $=o$, we obtain

$$(1-q(\text{tang } nx=n(a-ql)$$

or

$$\text{tang } nx=na\frac{\left(1-q\frac{l}{a}\right)}{1-q}$$

in which x locates the point of centro-flexure, and a the load. There is most doubt as to the relation of x and a when these quantities are small. When very small the tangent approximates the arc, when the fraction to na is less than 1, which makes x less than a.

Trying (65), the 2d number $=o$ when $\sin n(l-x)=o$, or $n(l-x)=o$, π, 2π, &c. But $x=l$ when $n(l-x)=o$

$$x=l-\frac{\pi}{n} \text{ when } n(l-x)=\pi$$

But according to eq. (59) and Fig. 12, x in (65) has no value within the limits of the beam for a varying from o to l.

Hence we conclude that the point of contrary flexure is always between the load Q, and the fixed end of the beam, and it is difficult to tell which is the greater except in particular cases.

The point of maximum moment is to be found where the 2d member of (65) is a maximum. This occurs where

$$\sin n(l-x)=1 \text{ or } n(l-x)=\frac{\pi}{2}$$

$$\therefore \quad x=l-\frac{\pi}{2n} \quad . \quad . \quad . \quad (60).$$

if we ignore a. But considering a, it appears that the max. moment of flexure is always at Q, except when a is =, or less than x in (60); conditions identical with case X, as regards the one point H, Fig. 12.

Either member of (64) makes the moment at A where x and $y=o$

$$=-Q(ql-a) \quad . \quad . \quad . \quad (66).$$

But where $x=a$, the other limit of x for this expression, the moment is

$$-Ty-Qq(l-a)=$$

$$-\frac{Q}{n}\Big(n(ql-a)\cos na-(q-1)\sin na \quad (67).$$

and it is difficult to tell which is the greater, except in particular cases.

An inspection of figure 13 shows that if the compression T can be great enough to hold the beam in a curve while Q is zero, the force P will be reversed. Now, if Q be given some real positive value increasing from zero up, it will eventually make $P=o$. But by (63), when $P=o$, $q=o$. Hence to find the relation between T and Q for this, make $q=o$ in (64) and (65.)

XII. *Take the conditions as in* XI. *except change T to tension.*

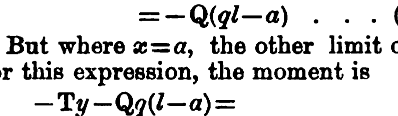


Figure 14.

1st. For the part AC, origin of co-ordinates at A, and y positive downward,

$$\epsilon I\frac{d^2y}{dx^2}=+Ty+Q(a-x)-P(l-x)$$

$$=Py-(Q-P)x+(Qa-Pl)$$

Integrating by aid of (13) and determining the constants by the conditions $x=o$, for $y=o$, and $\frac{dy}{dx}=o$ for $x=o$ we get an equation of the curve of the axis of the beam AC, and also the moment of flexure

$$Ty-(Q-P)x-(Qa-Pl)=$$

$$\frac{Qa-Pl}{2}\left(e^{nx}+e^{-nx}\right)-$$

$$\frac{Q-P}{2n}\left(e^{nx}-e^{-nx}\right)=M \quad . \quad . \quad . \quad (68).$$

But P is here an unknown quantity, and is to be found as it was in XI.

2d. For BC

$$\epsilon I\frac{d^2y}{dx^2}=Ty-P(l-x)$$

$$=Ty+Px-Pl$$

which may be integrated by (13), for $x=l$, $y=o$; giving value to one constant. Then place tang i, for the point C equal the same from (68), making known the second constant. Then equate the ordinates y for the point C, by which to determine P. The work is too tedious to detail here, but the result is

$$\frac{P}{Q}=$$

$$\frac{e^{-nl}-e^{nl}-e^{-n(l-a)}+e^{n(l-a)}+na\left(e^{nl}+e^{-nl}\right)}{e^{-nl}-e^{nl}+nl\left(e^{nl}+e^{-nl}\right)}$$

$$. \quad . \quad . \quad (69).$$

When $a=l$ $P=Q$, and when $a=o$, $P=O$; which are correct for these points and verify the result.

The maximum moment of strain for the whole beam, and under all conditions is probably at A, as it is at this point for the case that $T=o$. The probability seems to become a certainty from the fact that when T exists, its moment, which is counter to that of Q, is greatest where the deflection is greatest, or at intermediate points.

XIII. *Let the beam be fixed at both ends, be under tension T and have a load Q at the middle, and a uniformly distributed load.*

$$\epsilon I\frac{d^2y}{dx^2}=Ty+\frac{wx^2}{2}-Px+P_1(r+x)$$

$$=Ty+\frac{wx^2}{2}+(P_1-P)x+P_1r$$

$$\text{where } P=P\ +\frac{wl}{2}+\frac{Q}{2}$$

Integrating by aid of (13), and observing that for $x=o$, $y=o$, and that $\frac{dy}{dx}=o$, for $x=o$ and also for $x=\frac{l}{2}$; and we get,

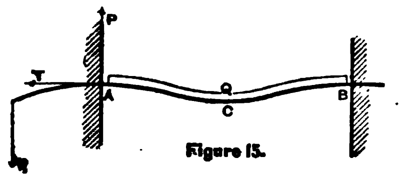


Figure 15.

after reduction, the general equation of moments and of the axis of beam

$$Ty+\frac{wx^2}{2}-\frac{wl+Q}{2}x+P_1r=\frac{wl+Q}{4n}\left(e^{-nx}-e^{nx}-\frac{2-\frac{2wl}{wl+Q}-e^{n\frac{l}{2}}-e^{-n\frac{l}{2}}}{e^{n\frac{l}{2}}-e^{-n\frac{l}{2}}}\left(e^{nx}+e^{-nx}\right)\right)$$

$$-\frac{w}{n^2}=M \quad . \quad . \quad . \quad (70).$$

In case the load is only Q, make $w=o$, or if we have only the uniform load, make $Q=o$ and the resulting expressions will give the moment of flexure at any point in the length of the beam.

At the point A, the moment is a max. and formed by making $x=o$, and $y=o$. Hence, as P_1r=moment at A, we have,

$$P_1r=\frac{\frac{wl}{n}}{e^{n\frac{l}{2}}-e^{-n\frac{l}{2}}}+\frac{wl+Q}{2n}.$$

$$\frac{e^{n\frac{l}{4}}-e^{-n\frac{l}{4}}}{e^{n\frac{l}{4}}+e^{-n\frac{l}{4}}}-\frac{w}{n^2}=M_{max} \quad . \quad . \quad (71).$$

When $w=o$, (71) becomes

$$P_1r=\frac{Q}{2n}\frac{e^{n\frac{l}{4}}-e^{-n\frac{l}{4}}}{e^{n\frac{l}{4}}+e^{-n\frac{l}{4}}}=M_{max} \quad . \quad (72).$$

But when $Q=o$, (71) becomes

$$P_1r=\frac{wl}{2n}\frac{e^{n\frac{l}{2}}+e^{-n\frac{l}{2}}}{e^{n\frac{l}{2}}-e^{-n\frac{l}{2}}}-\frac{w}{n^2}=M_{max} \quad . \quad . \quad (73).$$

At the middle of the beam $x=\frac{l}{2}$ and the moment, for $w=o$, is the same as (72) except the sign is contrary.

But for $Q=o$; instead of (73) we have

$$\frac{\frac{wl}{n}}{e^{n\frac{l}{2}}-e^{-n\frac{l}{2}}}-\frac{w}{n^2}=M \quad . \quad . \quad . \quad (74).$$

The four last equations give the moments most likely to be needed, and the value of P_1r put in (70) gives us the equation of the curve of AQ and BQ is like it.

XIV. *Take the case as in* XIII., *except change* T *to compression.*

$$\epsilon I\frac{d^2y}{dx^2}=-Ty-Px+\frac{wx^2}{2}+P_1(r+x)$$

$$=-Ty-(P-P_1)x+\frac{wx^2}{2}+P_1r$$

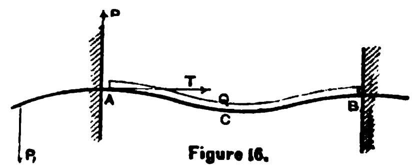


Figure 16.

Integrating by aid of (15), and observing that for $x=o$, $y=o$; and that $\frac{dy}{dx}=o$ for $x=o$ and for $x=\frac{l}{2}$; we obtain

$$-Ty-\frac{wl+Q}{2}x+\frac{w}{2}x^2+P_1r=$$

$$=-\frac{wl+Q}{2n}\left(\sin nx+\cot n\frac{l}{2}\cos nx\right)$$

$$+\frac{Q}{2n}\cdot\frac{\cos nx}{\sin n\frac{l}{2}}+\frac{w}{n^2}=M \quad . \quad . \quad (75).$$

At A, x and $y=o$, and

$$P_1r=-\frac{wl+Q}{2n}\cot n\frac{l}{2}+$$

$$\frac{Q}{2n}\frac{1}{\sin n\frac{l}{2}}+\frac{w}{n^2}=M_{max} \quad . \quad . \quad . \quad (76).$$

When $w=o$ (76), becomes

$$\frac{Q}{2n}\text{tang } n\frac{l}{4}=M_{max} \quad . \quad . \quad . \quad . \quad (77).$$

essentially the same as (58).

But when $Q=o$ in (76), we have

$$P_1r=-\frac{wl}{2n}\cot n\frac{l}{2}+\frac{w}{n^2}=M_{max} \quad . \quad . \quad . \quad (78).$$

This is the same as at B, where $x=l$. Q still $=o$

At the middle of the beam $x=\frac{l}{2}$, and the moment for $w=o$, is the same as (77) except the sign is contrary. But for $Q=o$, instead of (78).

$$-\frac{wl}{2n \sin n\frac{l}{2}}+\frac{w}{n^2}=M \quad . \quad . \quad . \quad (79).$$

Thus the most needed moments are obtained, and the equation of the elastic axis of the beam is fully given, P_1r, in (75), being made known by (76).

CHRONOGRAPH FOR ENGINEERING PURPOSES, WITH THE HIPP ESCAPEMENT.

By W. R. ECKART, C.E.

Read at the Philadelphia Session, Am. Society of Mechanical Engineers, April, 1882.

Having for a number of years felt the need of some instrument for measuring and recording the velocity of Pumping machinery which I have been brought in contact with, professionally, at the deep mines on the Comstock Lode, where the irregularity due to long and heavy pump rods as well as other masses in motion were greatly felt, I was forcibly impressed with an article by Robert Briggs, C.E. (Journal Franklin Institute, 1877, Page 89), describing the "Hipp Escapement" and its adaptability to the purposes I desired.

I corresponded with that gentleman, and he had constructed for me in Philadelphia, the escapement and driving gear now used (for a detailed account of the Hipp escapement, I must refer to his paper on that subject). But the revolving drum and other arranged parts of the instrument had to be changed, as no way of recording the curves of motion on paper could be used that produced perceptible friction (such as pencils or ink); and on account of the exceeding sensitiveness of the controlling spring of the escapement, great care was required in securing a perfect balance of the revolving drums with ease of motion, without the use of heavy driving weights; in other words, all parts of the instrument had to be made as sensitive as possible, so as to require the least possible weights to produce the desired motion.

In the start numerous failures had to be put up with for not paying attention to these points of construction, and even now, if the recording paper is not properly put on the revolving drum, a slight excess of weight on one side of the drum, such as that due to lapping the paper, will produce a perceptible change of sound from the escapement spring, indicating an acceleration or retardation of motion, according as the excess is on the descending or ascending side of the drum. In covering the drum with paper I have found it desirable to cut the sheets some ⅜ or ¼ inch less than the exact circumference of the drum, and to unite the edges by means of a strip of paper mucilaged and lapping slightly on each edge. The whole joint is then thinned down with fine sand paper to equal weight and smoothness—the whole sheet is covered with a coating of lamp black from a suitable hand lamp, and is then ready to receive the curve of motion.

The tracers, both for recording seconds as well as the velocity curve of the engine, are made of flat strips of spring steel, the axis of each being pivoted at the end on adjustable screw centers to prevent lost motion. By means of a small steel wire and weight extending to the opposite side, the tracers can be made to bear as lightly as desirable on the paper, and when properly adjusted the pressure is only sufficient to remove the lamp black without touching the paper, thereby leaving a fine white line on the dark back ground with the least possible interruption of motion. The whole is permanently set by dipping the face in a thin solution of shellac.

Instead of using a pendulum for producing (through an electro-magnet), the marks spacing seconds on the paper, which is the usual device, some other method was found necessary that would admit of greater compactness and portability; for the chronograph was to be used, not only on the surface where the pumping engines were situated, but it had to be adapted to underground use. And those who are acquainted with the general arrangement of a deep mine pumping compartment, especially on the Comstock, where the air is heavily surcharged with steam from the excessively hot water of the mines, know, that the difficulties to be overcome were not slight, and compactness was absolutely necessary, as the whole instrument when in use, had, not only to be protected from the steam and dripping water, but had to be set up in such cramped spaces as could be found available, without any further preparations, and the time for adjusting the instrument as a whole ready for use, had, in all cases to be as limited as possible, as the temperature in which I was obliged to take diagrams sometimes reached 110°.

After numerous experiments, the use of a chronoscope (or timer), such as is to be had for timing horse races, was made to give satisfactory results. (See Fig. 1.) The method adopted was as follows:—A stand or base plate upon which the timer was placed had a brass stanchion suspending a fine platinum wire directly over the second hand; this wire, when at rest, bore on a piece of platinum inserted in a rubber insulator projecting from the stanchion, each of these wires being connected in the usual manner through the electro-magnet on the chronograph to a two-cell battery. A circuit was always formed, except when the hand of the timer, revolving once every second, swings the suspended wire free from its metal bearing at the apex of the triangular notch cut in the rubber guide-piece; as contact was broken every revolution of the second hand, the armature of the electro-magnet recorded the same by a side movement of the steel tracer resting on the prepared paper of the drum.

The suspending wire was made adjustable in various directions to suit the second hand, and when once adjusted the whole instrument was covered with a glass case protecting it from moisture, and could be transported and used with rapidity and without further difficulty.

Mr Briggs states (in his paper above referred to) that Prof. Hilgard used a chronoscope for the Navy Ordnance Department, in which the second marks were 30 inches apart. I have found no trouble in speeding the revolving drum of 6″ diameter, until the second marks were 20 inches apart, but for practical use, a length of three to ten inches (depending somewhat on the engine speed), was all that was desired, and by use of a standard steel scale with the inch divided into hundredths, changes of motion taking place in the $\frac{1}{1000}$ part of a second, were easily read and recorded without trouble, and the crossing of lines due to the too frequent revolution of the recording drum during one stroke of the engine was avoided. The use of the small electro magnet,—on the tracer carriage, to raise for an instant the tracing pointer off of the drum at any desired point, was found necessary in determining the effects of elasticity in the interruption and variation of motion, where a *long* line of pump rods was used, and was also found useful in fixing, positively, the exact point of closing or opening of the steam valves of the engine, independent of all reference to the indicator cards taken.

Two drawings giving different views of the chronograph as constructed and used, are attached to this article, exhibiting details of construction to complete what otherwise might be considered a defetive description of the instrument.

It may not be out of place here to state that the instrument has been successfully applied to several of the different types of large pumping engines found on the Comstock Lode, such as Direct-Acting Fly-Wheel Engines, Geared Pumping Engines, and the "Davy Engines;" it has also been used to determine the motion and relative motion of pump rods, and pumps some 2500 feet below the surface engine driving same, and at intermediate points. The results are exceedingly interesting and instructive, and as numerous indicator cards were taken from the engines and pumps simultaneously with the motion diagrams, nearly all conditions of motion and power, during the time under consideration, were definitely determined, and may hereafter form the subject of other papers when time will permit.

Some very important results of the elasticity of long pump rods are clearly set forth in one case: A rod at a point 1800 feet below the surface showed a positive pause, while the engine driving it was nearly at its point of maximum motion, and pumps attached to the rods may have, and do have strokes in excess of, or deficient to the *stroke of engine driving same*, and to an *important extent.* Hence, I think, it can be definitely stated that any consideration of motion of pumps, or discharge capacity of same, driven by a long line of pump rods based upon the motion or stroke of a surface engine alone, will in no way be even approximate, unless the elasticity and effects of counter-balancing by balance bobs on that elasticity, is also considered.

The effects of different degrees of compression upon the engines and motion of the pump rods in passing the centers have been considered, and the diagrams clearly show the importance of considering it in connection with the strength of the rods and balance bobs.

My latest use of the instrument in conjunction with an engine test, has been to determine, if possible, the rate of condensation of steam per second, in the steam cylinders of a pumping engine, where the change of motion due to each fractional part of the stroke was determined. Also, a ten hour experiment trial, to show the economy of compression, as compared with a ten-hour trial of the same engine on the succeeding day where no compression was used, (otherwise all conditions being similar), has been made, when changes of velocity of piston were determined by the chronograph. I hope sometime to make public the results of these observations for the use and criticism of those interested, after the labor of working them up and tabulating them is completed.

While it is well known that a Committee of the British Association applied a chronograph of Morin's type in 1843 4, to the determination of the velocity of piston for a Cornish Pump Engine, I believe there was no application of the instrument to the rods below ground, and, from published records at my command, I am led to believe that this is the first application of a chronograph of sensitive construction ever made to pit work, and the other purposes so briefly mentioned.

Lettered Reference to Figures 1 and 2 of the Instrument.

CC—Cast iron base plate, covered with sheet brass, upon which the mechanism is secured.

B—Metal frame containing gearing for driving drum A, and escapement wheel *b*; motion communicated by means of adjustable weights, D.

AA—Light brass drum, accurately balanced, revolving on friction rollers 8, 8, at both ends.

ff—Parallel guide bars upon which the tracing point h_0 and its carriage travel back and forth, receiving motion in one direction from the engine or other moving parts, through the cord P, passing between the bars *f*, and attached to the tracing carriage —the return motion is derived from a coiled spring in the spring drum C.

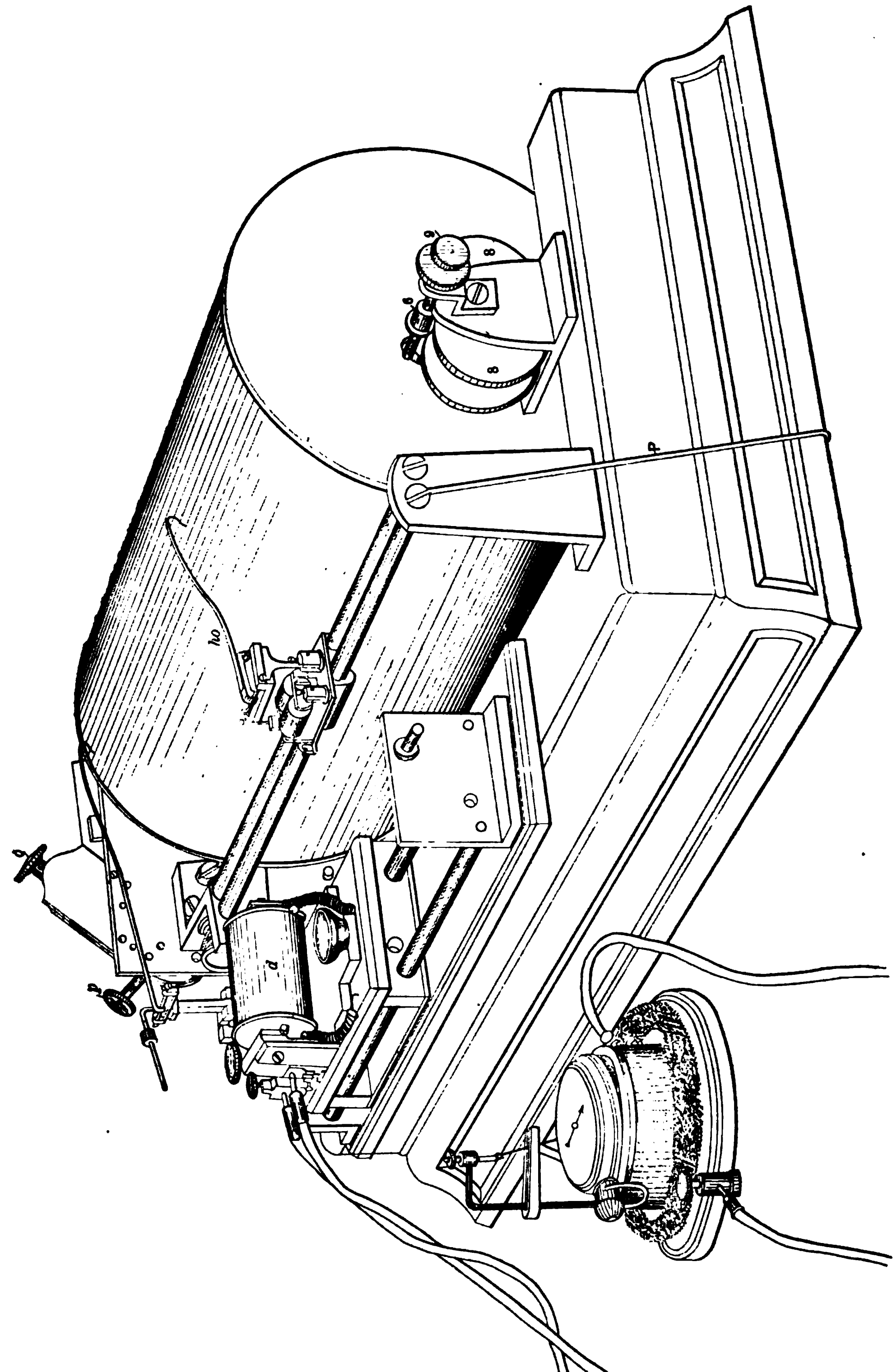
ee—Small electro-magnets on tracing carriage for raising the tracing point h_0 off of the paper and replacing it at any desired point to be especially observed.

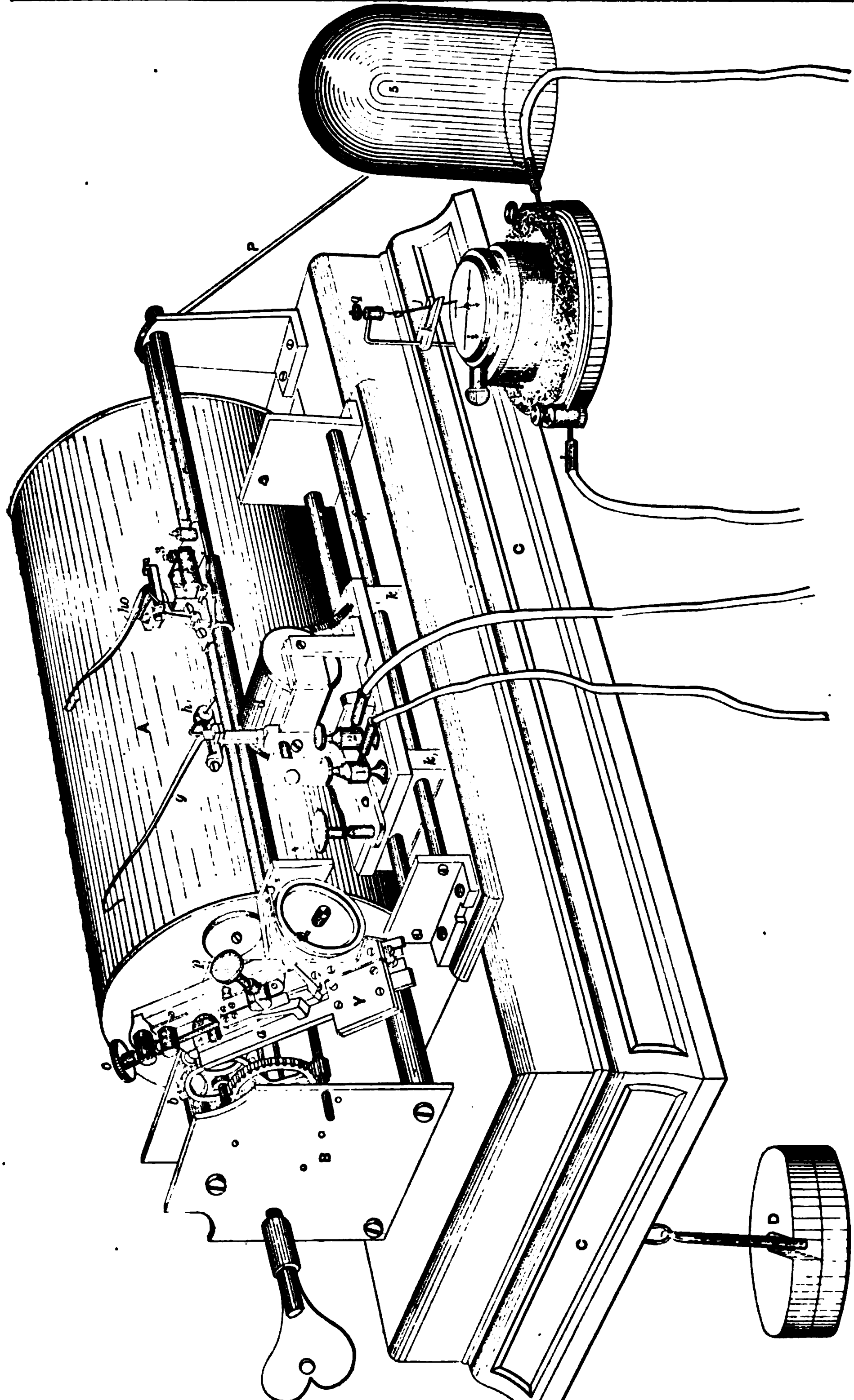
d—Electro-magnets on separate carriage *kk*, adjustable on parallel bars *f*, operating the steel tracing point *g*, attached to the armature of *d*, for the purpose of recording seconds on the margin of the paper or at other parts of same as required.

i—Chronoscope or watch supported on frame X, the second hand of which swings the light platinum wire J, breaking contact with the insulated wire *k*, thereby breaking circuit with *d* and recording seconds through the tracing point *g* on the paper.

q—Adjusting screw for the wire J.

a—Steel spring of escapement. This spring is securely clamped in Y, its flexibility being controlled to a certain extent by means of the thumb-screws *o* and *p*.





REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA, March 18th, 1882.

President Rudolph Hering presented notes on the Resistance to Traction on Streets, giving results compiled from various authors who had experimented on the subject. Resistance varies nearly as the weight, being great for heavy loads and almost nothing for light pleasure carriages. It increases on paved streets with the velocity and as the diameter of the wheels become less. The width of tire has little influence on hard and smooth roads, especially for light loads, while it has considerable influence on soft and rough roads, particularly when the load is heavy. The most economical conditions for traction, therefore, are a hard and smooth surface, large wheels and broad tires; the latter for heavy loads drawn on rough roads. To draw a load on sand requires a power equal to $\frac{1}{5}$ its weight, on ordinary earth $\frac{1}{10}$, on hard clay $\frac{1}{20}$, on ordinary cobble stones $\frac{1}{15}$, on good cobble pavements $\frac{1}{30}$, on ordinary Belgian blocks $\frac{1}{40}$, on London blocks $\frac{1}{65}$, on asphalt $\frac{1}{125}$, and on iron rails $\frac{1}{200}$ of the load.

The economy in horse power obtained by using the hardest and smoothest roads is clearly shown. If one horse can just draw a load on a level, over iron rails, it will take $1\frac{5}{8}$ horse to draw it over asphalt, $3\frac{1}{4}$ over the best Belgian, 5 over ordinary Belgian, 7 over a good cobble stone, 13 over a bad cobble stone, 20 over an ordinary earth road, and 40 over a sandy road.

Mr. D. H. Shedaker exhibited a large and very complete work on "The Art of Surveying," by John Wing, published in 1699, and presented Report of Mr. Heber S. Thompson, Engineer Girard Estate, upon the extinguishment of the fire at Kehley's Run Colliery.

Mr. W. S. Auchincloss exhibited his averaging machine, which consists of a stand with two uprights which support a rectangular pan 29″ long and about 10″ wide. The edges of this pan are formed of tubes, which slide through the bearings and enclose rods forming counterweights. These rods are connected by pulleys with the pan so that, when it is moved in one direction, they move in the other and so preserve the equilibrim.

The pan is divided into equal grooves at right angles to its length.

Paper scales, graduated for various uses, accompany the machine, and the adjustment is so accurate that the absence of a scale, which forms part of the balanced weight of the pan, throws the machine entirely out of balance. A convenient series of weights is provided to compose the quantities to be averaged. We place these in the grooves opposite their appropriate points on the scale, slide the pan until in equilibrium and read the average at once from the scale, at the point of support.

This machine was designed especially to average commercial accounts, and can solve one hundred accounts per hour and work both sides of ledger at once; but it is also adapted to ascertain average haul of earth, speed of pulleys, &c.

The Secretary presented a description of Defenbach's rail joint.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The Society met at its House in 23d Street, New York. Wednesday Evening, April 5th. President Ashbel Welch in the chair.

Arrangements were made for the Annual Convention of the Society to be held in Washington, May 16th, prox., and succeeding days. The introduction of a bill in Congress was announced for establishing a Commission composed of persons skilled in the investigation, production and use of Metallic Substances and other Structural Materials. The great importance of the speedy passage of this bill to the future safe and economical construction of Bridges, Roofs, Floors, Iron or Steel Ships, Ordnance and Armor and all structures in which metal is extensively used was forcibly presented.

A paper by A. P. Boller, M. Am. Soc. C.E., on the Mode of Underpinning adopted for the Croton Lake Bridge, New York City, and Northern R. R. during the Repairs to the Masonry Piers, was read by the Secretary. This Bridge was a single track, wrought iron, deck structure, in three spans of 160 feet each, with skeleton wrought iron piers or towers springing from blocks of masonry. The water was 80 feet in depth. These towers had four legs and thus concentrated all the weight upon the four corners of the masonry. This masonry had been built ten years before by another company. It rested below low water upon timber cribs. It was tested by loading with stone before building the iron bridge without showing improper settlement. The erection of the bridge towers and the use of the bridge soon developed the fact that the masonry could not stand the weight upon its corners and it became necessary to rebuild it. The towers being continuous frame works with spreading legs made it practicable to build inside of them a subsidiary wooden tower with perpendicular legs. This was done, the bottom wood sills being placed so as to admit the introduction of weight 20 ton hydraulic jacks. Two minutes work with the jacks lifted the towers and adjoining spans bodily. They were then supported upon 15-in. rolled beams, 200 lbs. to the yard, placed in pairs, resting on the inner side upon timbers distributing the weight upon the masonry, and on the outer sides on timber supports built up from the original crib work. The defective masonry was then taken out and rebuilt. One half hour sufficed to raise the structure, throw the weight upon the cross girders and resume traffic.

No train was delayed on its schedule time.

The author criticises severely the character of the old masonry.

The subject of the overflow of the Mississippi was also discussed.

ENGINEERING NOTES.

THE PANAMA CANAL.—The November rains delayed the progress of the works, and the accounts now received by mail do not give much of interest as the result of the labors of that month. The houses at Colon for workmen and superintendents and their wives are making progress, and some are completed, as is the main body of the hospital. The company has purchased another large piece of ground in the island of Mauzainlo, for the reception of machines, stores, &c., between their arrival by sea and despatch by rail. The steam sloop Nina, a flat-bottomed lighter, and three barges, have been launched at Colon. The third excavator and two steam windlasses have been set up, and rails laid down temporarily on the newly purchased land in connection with the railways at Folks river. Similar preparatory work has been carried on at other stations, and Lesseps City has made progress. New villages are being marked out at Gamboa and Emperador; the old village at the former place will be submerged when the great artificial lake is formed. The San Pablo sounding has only gone 20 feet deep as yet, and has found a superficial layer of vegetable soil, under which is a soft argillacious tufa. Opposite Gamboa, hard rock has been met with at a depth of 10 feet, and as its surface is sharply inclined soundings are being made to ascertain its slope. At the Cerro Obispo a very hard black rock has been found at 20 feet, which is believed to be doleritic. Meteorological and hydrographical observations have been carefully carried on, but no remarkable phenomena have occurred. The fall of rain in the interior of the isthmus is not so great as it is at Colon, and it is still less at Panama. It is supposed that the Cordilleras catch some of the rain clouds coming from the north, and cause them to discharge upon the Atlantic coast. The temperature during the month of November has varied within the following limits: Colon, maximum 31 deg. 5 min. Cent., minimum 20 deg. 6 min.; Gamboa, maximum 37 deg. 5 min., minimum 20 deg.; Island of Naos (Panama) maximum 33 deg. 5 min., minimum, 22 deg.

The Canal from the Atlantic to the Mediterranean.—The Commission appointed by the French Government to investigate the plan for this canal, submitted by the surveying company presided over by M. Duclerc, has sent in an indecisive report. The proposed canal would be about 270 miles long, connecting Bordeaux and Narbonne with Toulouse as one of its ports. Its highest point would be 500 feet above the level of the sea. It would be supplied with water from the River Garonne and other minor sources, and would admit of the passage of ships of war. Its military advantages are those which appear most obvious; but its supporters also claim that it would be useful to agriculture by enabling the vine to be cultivated along its course. They expect a considerable revenue from irrigation and water-power rents, besides the ordinary tolls. The majority of the Commission estimate the total cost of construction at £56,666,160; and while considering the work practicable, decline to give an opinion as to whether or not it would be worth the expense. The minority assert that the construction would be exceptionally difficult, and that the canal when made would be of little or no use. The Commission concludes its report by advising that more detailed inquiries should be made into the agricultural and commercial conditions of the district through which the proposed canal would pass, and its probable effect upon them.

Proposed Tunnel Between Italy and Sicily.—A project for a tunnel between Reggio and Messina has been presented to the Minister of Public Works by the "Societa Veneta di Publicha Construzioni." The author of this project is Signor Federico Gabelli. The total length of this tunnel will be 13,200 meters, including the inclined approaches, or 1,000 meters longer than the Mont Cenis Tunnel. The maximum depth of water over the proposed tunnel will be 110 meters, the ends of which, at this place, would be 35 meters below the bottom of the sea. The direction of the submarine portion of the undertaking will be from S.E. to N.W., between the Punta Del Pizzo and Sta. Agata. The inclined approaches, 4,500 meters in length, will run parallel with the shore for a certain distance, and then, with a curve of 350 meters radius, join the tunnel under the straits, which will be 4,200 meters long, or rather more than 2½ miles. The gradient of the inclines is fixed at 2½ per 100, or the same as that on the line from Turin to Genoa at the Giovi Tunnel. The submarine portion will have a fall of ½ per 1,000 from the center towards the shore ends, in order that the filtrations of water may drain and be pumped out by engines, which will be fixed at the vertical shaft from which the tunnel will be driven. From a geological examination of the locality, it would appear that the bottom of the straits consist of crystalline rocks, such as granite, gneiss, and mica schist. The quatertiary formation that covers the crystalline rocks, both on the Sicilian and Calabrian coasts, is not supposed to run deep, and should fissures occur in the older formations, through which it is proposed to drive the tunnel, they are probably filled up with clay or mud, so that there will be no fear of water finding its way into the tunnel. According to Signor Gabelli, the cost of the undertaking will not exceed 65 millions of lire (£2,600,000), and could be completed in six years.

Channel Tunnel.—At a meeting of the Submarine Continental Railway Company, held on the 20th January, 1882, Colonel Beaumont described the process of making the tunnel, by means of machinery designed by himself and Captain English. He said, "Captain English's and my own machine is now heading at the rate of 12 yards per day of seventeen hours. We have every confidence that the machine which will next be put into the heading will drive at the rate of 1 yard of the heading per hour. If you have the same thing done on the French side, that will be 2 yards per hour, or in round numbers, 50 yards per day. . . The dirt that is cut by the machine is delivered in the wagons, so that this advance is actually got by the manual efforts of two men only. One man is employed at the face of the machine, and another man behind, driving it, and these two represent the only manual labor employed at the machine. The ventilation, which is of course a very important matter, and an absolute *sine qua non* in connection with the question of traffic through the tunnel, so far as the construction of the works is concerned, is provided by the air which is necessary to work the boring machine itself. . . . The amount of air which is required for working the machine is quite sufficient to keep the headings perfectly ventilated. . . Compressed air is now in such a position that it becomes quite a measurable quantity. You can estimate the amount of coal you have to burn to move a given amount of dirt. . . By the use of compressed air, and burning one pound of coal, you will move three tons a mile on a railway."

Great improvements and additions have been recently completed in the drainage of Walthamstow, under the direction of Mr G. B. Gerram, A.M.I.C.E. The defects in the sewerage were chiefly in the private streets. One of the principal works that have been executed consisted in providing sewers for draining Higham Hill, where before cesspools existed, which overflowed into the brook. The level of the main northern sewer was above that of the brook, and this has been got over by building a new invert, and raising the road some 4ft. 6in. in height, thus making the approach to Higham Hill much easier and more convenient The culvert is 8 feet in width and 4 feet high, the invert being curved and laid with Staffordshire blue bricks on edge, in cement, on a bed of concrete. This is covered over with iron girders, and jack arches covered with concrete. The sewer recently laid is over six miles in length, and over 28,000 cubic yards of earth have been excavated. Junction pipes are laid at intervals of 30 feet and 40 feet, so as to avoid any necessity of breaking the sewers to make any connection therewith. The works have been executed by Messrs. Currall and Lewis, contractors of Birmingham. The construction of the surface-water drains has prevented any flooding of the sewage farm during the recent extraordinary floods in the Lee Valley, thereby removing one of the causes of difference between the Local Board and their tenant.

RAILWAY NOTES.

The long-projected railway bridge over the Hoogly, which will enable the East India Railway to be run direct into Calcutta, is, it is stated, to be taken in hand immediately. The main features of the bridge is three wrought iron girders, each 400 feet long. The cost will be £275,000, and will be borne by the Government. The work will occupy three or four years.

Earl Delaware will, during the approaching session, introduce a bill the object of which is to make the use of continuous brakes on railways compulsory. It will be proposed that after the 1st of February, 1885, every company shall have in connection with each passenger train a continuous brake, which shall be efficient in stopping the train, instantaneous in action, and applicable without difficulty. It must also be immediately self-acting in case of accident, capable of being easily removed, and be of durable material. The brake in each vehicle of a train is to be susceptible of being worked as part of one system. The Board of Trade is to have power to inspect rolling stock, especially with a view to the use of the brake.

It is estimated that 7500 miles of new railway were constructed last year in the United States; and, according to the Philadelphia correspondent of the *Times*, no less than 18,000 miles of new railway are projected for the current year. A comparison of the new mileage of 1881, with that of each of the previous nine years shows the following result:—1872, 7340 miles; 1873, 3883 miles; 1874, 2 25 miles; 1875, 1561 miles; 1876, 2460 miles; 1877, 2308 miles; 1878, 2916 miles; 1879, 4430 miles; 1880, 5839 miles; 1881, 7500 miles. Capital is thus being set fast in new railroad undertakings, with greater rapidity than during the railway mania which culminated in 1872. It is true that now the States are much better populated and far wealthier than they were nine or ten years ago; they thus need and can afford to provide much more ample means of communication.

In concluding his report on the collision which occurred on the 9th of December, near the Manchester Central Station of the Cheshire Lines Committee during a thick fog, Major General Hutchinson says: "The speed would certainly have been far more rapidly reduced, and the collision have been mitigated in its results or altogether avoided, had the engine and tender as well as the train been fitted with a quickly acting continuous brake." It has now been decided to apply air brake fittings to the Manchester, Sheffield and Lincolnshire Company's engines and tenders, as well as to the vehicles composing the train The Chester train was forgotten after it had passed out of sight of the signalman at West Cornbrook Junction, and this fact, he says, calls attention to the expediency of some means being adopted to guard against this contingency. He suggests that "in cases of this kind, where a train or engine is stopped from fog or other causes out of sight of a signalman, the guard or fireman should be instructed to go back to the signal cabin, and remain there until the signalman is able to allow the train or engine to proceed."

ORDNANCE AND NAVAL.

The s.s. Jacob Christensen, which has been built by Messrs. Raylton, Dixon & Co., Middlesborough, to the order of Hans Konow & Co., of Copenhagen, has proceeded on her trial trip. She is a handsome iron screw steamer, 269 feet long, 34 ft. 9 in. beam, 24 ft. 3 in. depth of hold, which gives her a carrying capacity of 2,500 tons on 22 feet draught. She is built as a three-decked steamer, having main deck of iron and upper of wood. Her water ballast is contained in a large chamber in the main hold forward of engine room, which is also available for storage of cargo. She is fitted with a short poop aft, in which are commodious cabins for captain, officers, and two or three passengers. Higginson's steam quarter master steers her from the bridge, and she is fitted with steam winches and self-reefing topsails. Her engines, of 150 horse power nominal, are by Messrs. T. Richardson and Son, of Hartlepool, and gave every satisfaction on her trial trip.

Mountain Horse Artillery.—In the Russian Army List may be found two batteries bearing this description. One of these has been stationed in Turkestan since 1876, and the other (which has only recently been formed) is in Western Siberia. A long article was published in the *Artilleriesky Journal* of October, 1881, on this artillery, which was designed to accompany cavalry in the most mountainous districts, where ordinary artillery could not travel. The guns are three-pounders of the regulation pattern, and are mounted on mountain carriages, the trail of which is attached to a lumber of special construction. This latter consists simply of two wheels, on the axle of which is mounted an iron basket capable of containing two ammunition boxes, each holdseven rounds. To the axle is attached an ordinary field artillery pole. Four horses are employed, driven in pairs in the ordinary way. The ammunition wagon is of similar construction to the limber, but the basket is made to carry four ammunition boxes. It is furnished with double poles, and drawn by three horses abreast. All the draught horses are furnished with pack saddles, upon which can be transported the guns and equipment, should it be necessary to dismount them for transport over country where wheeled vehicles could not pass. All the men are mounted, and their saddles are so arranged as to carry the wheels, poles, shafts, whipple trees, &c.; seventeen men are attached to each gun, the corporal of the gun, ten gunners, three drivers, and three horsekeepers. Four of the gunners are considered as reserve, to replace those who may be disabled in action. To every two guns (which form a section of a battery) are a sergeant and trumpeter, and four réserve horses, giving a total for two guns of thirty-six men and forty-eight horses. In November, 1880, a section attached to a special detachment of cavalry made an eight days' march across the Kopet Dagh mountains. Each day they traveled fifty versts, and on the last day of the march eighty versts were accomplished. A short time afterwards this section took part in the attack of Geok Tepe, and is said never to have hampered the movements of the cavalry, but rather to have been a valuable auxiliary. Still the construction of the material left much to be desired. When the guns and carriages were mounted on the pack saddles the men had to dismount and lead their horses: and as, of course, this only occurred in the most difficult country, the speed and length of the marches were limited by the endurance of the men. Moreover, it was only possible to carry forty-two rounds for each gun. The writer of the article proposes several modifications, which he considers will obviate these objections. The carriages, limbers, and wagons must be construc'ed in such a manner as to be easily dismounted into a number of pieces, so as to reduce the load for each horse, and to enable the men to ride instead of leading the horses. He also considers it indispensable to alter the construction of the ammunition wagon. This he proposes to do by attaching it to a limber similar to that of the gun. This would increase the number of rounds to fifty-six, whilst permitting the same system of draught to be employed as that which proved satisfactory with the gun. This latter could easily pass over obstacles which proved insurmountable to the wagon with its three horses abreast.

The new tea steamer, the "Stirling Castle," built by Messrs. John Elder & Co. for Messrs. Thos. Skinner & Co., was tried in the Clyde on March 17th and 18th, and gave a speed which shows her to be the fastest ocean-going steamer in the world. In the course of a run of six hours on Friday, she gave an average speed of 18.18 knots, and on Saturday six consecutive runs at the measured mile gave a mean speed, calculated on the Admiralty method, of 13.418 knots, or $21\frac{3}{10}$ miles per hour. The actual time taken in running each mile respectively was 3 min. 13 sec.; 3 min. 23 sec.; 3 min. 12 sec; 3 min. 18 sec; 3 min. 13 sec.; and 3 min. 18 sec. On the trial there was a cargo of 3000 tons dead weight on board ready for the voyage out. Her length is 430ft., breadth 50ft, and depth 33ft., and she registers 4300 tons. Her engines are the three-cylinder type, and have developed 8237-horse power. The diameter of the high pressure cylinder is 62in., and the two low pressure 90in., with a 5ft. 6in. stroke. Surface condensers are used with Gwynne's "Invincible" circulating pumps. The boilers are of steel, and present a total heating surface of 21,161ft.· the grate surface is 787 square feet; and the working pressure 100 lbs. to the square inch. The propeller is made of manganese bronze, is 22ft. 4in. in diameter, with a pitch of 31ft. The maximum number of revolutions at the trial was $66\frac{1}{2}$ per minute, accompanied by absolutely no vibration, except in the immediate vicinity of the screw shaft. The hull is built of steel, on plans approved by the Admiralty, with a view to national requirements, and is capable of carrying coal for a twenty days' cruise. Great interest is attached to the performance of the vessel, as she may be regarded as first favorite in the annual tea race.—*Engineer.*

German Bronze Guns.—The German artillery possesses seven different types of weapons of this material, the heavy 9-centimeter and 12-centimeter guns, the short 15-centimeter gun, the 15-centimeter gun with flat wedge breech-block, the 9 centimeter and 15-centimeter mortars, and the 21-centimeter howitzer, which is only now in course of construction. The heavy 9-centimeter gun has a round wedge breech-block, with the 1878 pattern safety ring. The vent tube passes through the tube and breech block. A special iron carriage has been made for fortress purposes, but the gun can also be used with the ordinary field carriage. The heavy 12.centimeter gun is of similar construction, but with copper fittings for the breech block. The carriage is formed of two iron frames strengthened with ties riveted on the inner sides. Five degrees of depression and 48 degrees of elevation can be attained. The projectiles have five copper windage rings. The 9-centimeter mortar has a screw breech-block, in which is the powder chamber. The vent tube—which is vertical—passes through the block. No elevating screw is required, the weapon being balanced on the carriage, which consists of two wooden frames secured by three bolts. On the front one of these bolts is the sight, and an elevation scale is attached to the hinder one. This carriage (which has no wheels) has the advantge of a very large base, with its center of gravity very low. The 15-centimeter mortar (which is not yet completed) will be similar in construction. No details of the design of the howitzer are to hand, as the construction has not yet been definitely decided.

The following are the more important weights and measurements:

——	9-cm. Cannon.	12-cm. Cannon.	9-cm. Mortar.	15-cm. Mortar.
Caliber in milim'tr's	88	121	88	
Length of bore.....	....	9ft. 2½in.	20 in.	
Number of grooves	24	30	24	
Weight of gun complete..............	8 cwt.	25½ cwt.	2 cwt.	
Total weight of gun and carriage.....	24 cwt.	45 cwt.	4 cwt.	
Weight of charge..	3.3 lb.	7.7 lb.		
Weight of common shell..	15.4 lb.	35 lb.	15.5lb.	89 lb.
Weight of shrapnel	18 lb.	43.12 lb.		
Weight of bursting charge of common shell	9.85 oz.	2.27 lb.	9.85oz.	4.18lb.
Weight of bursting charge of shrapnel	8 oz.			
Initial velocity of common shell ...	1480 ft.	1433 ft.		
Initial velocity of shrapnel..........	1390 ft.	1300 ft.		
Extreme range of common shell....	7700 yds.	8350 yds.		
Extreme range of shrapnel	2750 yds.	4600 yds.		

MACHINE GUN TRIALS.—Experiments have recently been made in France with the English Admiralty pattern Nordenfelt machine gun, with a view of enabling the French authorities to compare its efficiency with that of the far heavier Hotchkiss revolving cannon, throwing explosive shells of over 2 lbs. weight, as against the Nordenfelt 7 oz. solid steel bullet, previously adopted by the French Admiralty. The experiments were carried out with the greatest secrecy; but we (*Morning Post*) hear from Cherbourg that the French authorities are no longer so satisfied with their anti-torpedo boat gun, of which they have pure chased some 600, as they were prior to these trials. It is asserted in Cherbourg that the Nordenfelt English Admiralty pattern machine gun will be added to the equipment of several classes of French war vessels. The Nordenfelt works are now turning out an improved shell firing gun capable of firing from 15 to 30 rounds a minute. This gun does not weigh a fourth of the weight of the Hotchkiss revolving cannon. Its muzzle velocity and penetration are, however, vastly superior to anything of the kind as yet produced, and the recent trials made at Portsmouth by the Admiralty have proved that this gun is far superior in every way to the Hotchkiss revolving cannon. The Austrians recently used their Nordenfelt naval guns, throwing 7 oz. solid steel bullets, against the insurgents with good effect. But firing such projectiles at men scattered over a large extent of country is somewhat similar to firing heavy ordnance solid shot at sparrows. Explosive shells are required on such occasions and when the guns have to be worked on land, in a mountainous district especially, the lighter they are the better. The Hotthkiss revolving cannon weighs somewhat over a ton, the Nordenfelt shell-firing gun under five hundred weight, a difference in weight which renders the latter gun by far the most serviceable.

IRON AND STEEL NOTES.

KRUPP'S WORKS AT ESSEN.—This establishment was founded in 1810 by the father of the present proprietor, and in 1848 it employed 74 workmen. At the present time about 17,000 persons are engaged. There are at work 1,542 furnaces, 294 boilers, 82 steam hammers varying from 2 cwt. to 50 tons, 310 steam engines of from 2 to 1,000 horse power each, giving a total of 12,000 horse power, and 1,622 machine tools. In addition to this there are 14 blast furnaces, producing 600 tons of pig iron in twenty-four hours. The average daily consumption of coal and coke (including the blast furnaces and several steamers) is 2680 tons. The transport of the material used in the works employs 23 locomotives, 767 wagons, running on 42 miles of track, 50 horses, and 206 carts, while communication between the various departments is maintained by 48 miles of telegraph wires, with 35 stations. The mines belonging to the firm consist of 4 collieries, 547 ironstone mines in Germany, and a large number in the north of Spain. Their daily output is 3,000 tons of coal, 1,600 tons of iron ore, of which 1,200 tons are raised in Germany. The transport of the Spanish ore occupies five steamers belonging to the firm, with a tonnage of 7,800 tons.—*London Mining Journal.*

THE MANUFACTURE OF SOFT STEEL.—At Redbrook Works, Monmouthshire, on Friday last, in presence of an influential gathering of tinplate owners and others interested in the trade, some experiments were conducted in the new converter, patented by Mr. T. Griffiths of Blaenavon, which is intended for the production of soft steel suitable for tinplate. It is a fixed, upright converter of very simple construction, and costs very little in com parison with the other steel-making plant. The chief novelty lies in the arrangement and construction of the tuyeres, coupled with the use of low-pressure blast, 4 lbs. to the square inch. The steel made was of excellent quality, and some plates were shown made from a former blow, which were everything that could be desired and free from streaks or spots. It is admitted by most authorities that steel is suitable for nearly all purposes to which iron has hitherto been applied: We have an exemplification of this in the manufacture of tin bar and soft steel bars, producing less waste and cleaner plates, so that this converter should find favor with plate makers on account of its low cost, simplicity, and the excellent quality of steel.—*London Colliery Guardian, March* 10.

The iron and steel exports from Great Britain amounted last year to 3,818,388 tons. In 1880 it was 3,787,271 tons. The imports of iron, iron ore, steel, and tin in the same years were 2,587,981 tons in 1881, and 2,779,958 tons in 1880. The value of exported iron, steel, machinery, hardware, &c., was £42,381,662 in 1880, and £43,353,021 in 1881.

Tempering by Pressure.—A new method of tempering metals has been brought to the notice of the French Academy of Sciences by M. Clemandot. It consists in heating the metals to a cherry red and then compressing them strongly and maintaining the pressure until they have completely cooled. Metals thus treated acquire a great hardness and so fine a grain that when polished they resemble nickel. Compressed steel, like tempered steel, takes the coercive force which gives it the property of being permanently magnetized. As regards the duration of the magnetism, M. Clemandot states that the magnets of the Gower, Bell, and Ader telephones made of this new steel several moths ago have thus far preserved their force. As in ordinary tempering, M. Clemandot thinks the new process produces an amorphism in the metal; and he points out that it will now be possible to graduate a temper by graduating the pressure applied. In experimenting with different steel he finds those of Allevard always the best for magnetic purposes. Elliptical bars of steel seemed to take the pressure in all their parts, and showed a uniform fracture thoroughout. M. Clemandot's interesting discovery is likely to prove useful in the arts, and to open up a new field of study to electricians and metallurgists.

The Future of Iron.—The following passage, taken from an article on "Dephosphorization in the Converter," by M. Walrand (late manager of the Creuzot Steel-works, now of the Valenciennes Steel-works), which appears in the recent issue of the *Revue universelle des Mines*, deserves attention, as showing the views of a practical man on the immediate future of iron. M. Walrand observes: —"Those who are occupied in the manufacture of Bessemer steel know how difficult it is to obtain with regularity the extra soft steel employed for boilers in the French navy. Such metal appeared only to be made in the Martin furnace, and even then it was necessary to employ picked material in its manufacture. But by the new Bessemer dephosphorizing (Thomas-Gilchrist) process steels of an extraordinary degree of softness can be obtained with the greatest facility, and at a price less than that of ordinary rail steel. By treating a pig containing from 1.5 to 2 per cent. of manganese, we obtain, after the decarbonization and dephosphorization is finished, a non-oxydized metal which does not contain more than traces of carbon or manganese. If it be desired that the steel should be entirely free from any tendency to redshortness, we may add from 0 25 to 0.50 per cent. of a rich ferromanganese to remove any traces of oxygenization. The only precaution to be taken to obtain a soft steel is to choose pig (if direct working be employed) which contains sufficient manganese (with 2 per cent. as a maximum) or to make a suitable mixture of pigs if cupolas be employed. But this will be by no means the only outlet for dephosphorized metal, for up to the present time the high price of soft steel has been the great obstacle which has prevented many people from employing it in construction. But, by the new process, soft metal can be produced at a less price than ordinary (puddled) iron; there is, therefore, no longer any reason (apart from routine) why steel should not be employed in all cases in place of iron, to which it is so much superior in strength."

BOOK NOTICES.

PUBLICATIONS RECEIVED.

Minutes of the Proceedings of the Institution of Civil Engineers:

The Conservancy of Rivers. By William Henry Wheeler, M.I.C.E., and Arthur Jacob, M.I.C E.

The Forces and Strains of Recoil. By Henry Joseph Butter, M.I.C.E.

Iron Permanent Way. By Charles Wood, M.I.C.E.

Harlacher's Current Meter. By Richard Bloom.

History of the Water Supply of the World. By Thos. J. Bell. Cincinnati: P. G. Thomson.

Proceedings of the Society of Arts.—Boston, Mass: Institute of Technology.

Scientific Proceedings of the Ohio Mechanical Institute.

Constitutions and By-Laws of the Denver Society of Civil Engineers.

American Journal of Mathematics.—Baltimore: Johns Hopkins University.

Transactions of the American Institute of Mining Engineers. Advance sheets.

Report on a Water Supply for New York and other Cities of the Hudson Valley.—By J. T. Fanning, C.E.

A SYSTEMATIC HANDBOOK OF VOLUMETRIC ANALYSES.—By Francis Sutton, F.C.S. Fourth Edition. Philadelphia: Presley Blakiston. Price $5.00.

In the interval between the exhaustion of the third edition of this valuable book and the appearance of the fourth, the demand for the book was such as to bear strong testimony to the high estimate placed upon it by chemical students.

This edition is an improvement upon the old by reason of extensive revision and additions.

The author's methods are known and used wherever there are analytical chemical processes.

CANDLE POWER OF THE ELECTRIC LIGHT. BY PAGET HIGGS, LL D. New York. E. & F. N. Spon. Price 75 cts

This is a good enough book, what there is of it, which is very little. The little will prove attractive to a large number, because it relates so directly to one of the most important questions of public and also of domestic economy. But we are inclined to believe that the buyers everywhere will feel that both author and publisher have rated the essay above its value.

MUSICAL ACOUSTICS. BY JOHN BROADHOUSE. London: Wm. Reeves. Price $3.00.

This is a book for students, and presents in a an able manner all that the average student needs of the larger works of Helmholtz. It is well arranged and fully illustrated.

A PRACTICAL TREATISE ON HYDRAULIC AND WATER-SUPPLY ENGINEERING. By J. T. FANNING, C. E. Third Edition. New York: D. Van Nostrand. Price, $5.00.

This treatise is too well known to require an extended notice at this time. The fact that a third edition was demanded is sufficient evidence that the work is widely appreciated. It has long since become a familiar standard for reference. The three sections of the work are:

The collection and storage of water and its impurities.

Flow of water through sluices, pipes and channels.

Practical construction of water works.

Each of these is a complete practical treatise in itself.

THE ELEMENTS OF MODERN TACTICS. BY WILKINSON J. SHAW, M.A. Third Edition. London: Kegan Paul, French & Co. Price $3.50.

This forms the second volume of "Military Handbooks for Officers and Non-commissioned Officers."

The value of the book is enhanced largely by the excellence of the illustrations.

The separate chapters present in order the following topics:

Introduction—Functions of the three arms—Security and Information—Reconnoitering—Attack and Defense of Cavalry—Attack and Defense of the three arms—Rear Guards.

The book is of convenient size, and is well printed.

MISCELLANEOUS.

THE DEPHOSPHORIZATION PROCESS.—Doubts have recently been expressed as to the commercial success of the Thomas-Gilchrist dephosphorizing process, and it has been especially emphasized that the use of hematite ores has not been restricted by the basic process, but that, on the contrary, those ores are still largely employed. To this it has been replied that even the inventors of the new process have never dreamt of entirely superseding the Bessemer process by theirs; and Mr. Brauns, at a recent meeting of the German Iron and Steel Institute, expressly stated that the acid process, wherever suitable ores are obtainable, will keep its own as against the basic process As to the commercial success of the latter process, Mr. Thomas in a recent letter to us, cited facts which set at rest all doubts on the point. The *Essener Zietung*, arguing in support of that view, says that from those undeniable facts, it is evident that the commercial success of the dephosphorization process can no longer be denied. The apprehension, however, that the few German ores containing little phosphorus could be depreciated in value, is, according to our contemporary, entirely groundless. Already at the meeting of the German Iron and Steel Institute above referred to, attention was drawn to the fact that the manganiferous spiegeleisen of the Siegen district is as valuable for the manufacture of Thomas steel as of Bessemer steel. This value can only increase with the extension of steel-making.

THE POTENTIALS OF ELECTRIC SPARKS.—Sir William Thomson has made a great many experiments on the difference of potentials corresponding to electric sparks of different lengths across the air; but, a recent investigation of M. J. B. Baille on the same subject, but with somewhat longer sparks, furnishes results which are not quite in agreement with those of Sir William. The potentials of the latter physicist corresponding to sparks of a certain length are slightly less than those obtained by M. Baille for the same length of spark, and the discrepancy is attributed by M. Baille to Sir William Thomson having used a conductor which was constantly discharged by a continuous series of sparks, so that the potential was continually varying very rapidly, and only an intermediate value, somewhere between the maximum and minimum, could be obtained. M. Baille, though employing an absolute electrometer to measure the potentials, as did Sir William Thomson, took care to keep the difference of potentials constant during the measurements, by using a condenser that only gave sparks at long intervals. The potential was thus a maximum slowly attained, and the attraction also became a maximum at the moment of sparking. His results show generally that the potential of an electrified plate increases almost regularly with the sparking distance. The electric densities corresponding to different sparks decrease at first slowly and soon arrive at a constant value as is already known. The pressure exercised by the elec tricity on the air at the sparking moment for a distance of one centimeter is ony $\frac{1}{300}$ of the atmospheric pressure. We may add that the difference of potentials, as found by M. Baille, for a spark of 0.0025 centimeters is 1.90, that for 1 centimeter 14.67, that for 5 centimeters is 54.47, and that for 10 centimeters is 105.50 units.

REFLECTED ELECTRIC LIGHT.—The experiments which have been conducted on board the *Sultan* at Portsmouth, with a view of ascertaining whether the electric search lights in men-of-war could be protected from the guns of torpedo boats by the adoption of reflected light under cover, have been concluded. The official trial was witnessed by officers from the Admiralty and the War Department and from the local Torpedo School. Four different kinds of lenses were tested for purposes of comparison, the intensity of the electric beam being measured by a Bunsen's photometer and one of Sugg's burners. The apparatus used were a dioptric lens, a catoptric lens 90 centimeters in diameter, the ordinary aboveboard ship's glass, which was similar in character, but only 60 centimeters in diameter, and a reflector made of Chance's glass and silvered. The respective merits of each were found to be in the order mentioned, the dioptric producing double the illuminating power of the next best, and with an appreciable economy in cost.

THE uses of asbestos increase every year. Asbestos, in the form of a felt or tissue, is said to make a flood filtering medium for the chemical labratory, as it resists the action of corrosive acids as well as of fire. For the same reason, a pair of gloves woven from this substance is useful for handling acids. A sheet of asbestos card covering the table preserves it, and also prevents the breakage of small glass objects. Asbestos makes excellent porous cells for a galvanic battery; and kneaded with plastic clay affords a good luting for the stoppers of bottles. Asbestos paint, used to protect objects from fire, has also been lately manufactured.

FOR diminishing the danger of conflagrations in theatres, Signor Giovanni Abelo Martin recommends the following formulæ for rendering materials non-inflammable in the three cases below:—Mixture suitable for light tissues: Pure sulphate of ammonia, 8 parts; pure carbonate of ammonia, 2½ parts; boracic acid, 3 parts; starch, dextrine or gelatine, 2 parts; water 100 parts. (2) Mixture suitable for scenes already painted, timber work, furniture, doors and windows, to be applied like paint with a brush, at a temperature of about 140 deg. Fah.: Hydrochlorate of ammonia, 15 parts; boracic acid, 5 parts; glue, 50 parts; gelatine, 1 part, water 100 parts. (3) Mixture suitable for cloths, ropes and straw, which should be immersed for fifteen or twenty minutes, at a temperature of 212 deg. Fah., and allowed to dry. Hydrochlorate of ammonia, 15 parts; boracic acid, 6 parts; borax, 3 parts; water, 100 parts.

SOME time since the German Society for the Promotion of Industry offered a prize of 3000 marks for the best manganese alloys, with a view to obtain samples which might be tested for their physical qualities, especially their tensile resistance, and by this means to ascertain the influence of manganese on iron. The competitors were the Gutehoffnungs Iron Works, Oberhausen, and R. Selhof, engineer of the cast steel and arm factory, Witten. No less than 20 iron rods were required, which had all to be 50 centimeters long and 40mm thick. The first lot was to consist of an alloy of manganese and iron, of which the carbon did not reach 0.6 per cent., and all other substances were not allowed to exceed 0.4 per cent. The second set was to consist of carbon containing an alloy, manganese and iron, in which all other substances were not allowed to exceed 0.6 per cent. The chemical analysis and tests show that it is very difficult to mix alloys or different sorts of iron, that manganese is very easily oxidized and disappears from the alloy, and that when the rods were worked in a lathe or with a plane, and prepared for the tearing tests, they exhibited a large number of spots, showing that the amalgamation was imperfect. Notwithstanding that the results were not in accordance with the conditions, the society agreed to award the prize to the competitors on account of the trouble they had taken. The Gutehoffnungshutte having come nearer the conditions, was awarded two-thirds and Selhoff one-third of the prize offered.

WHAT would be the relation between the velocities of clouds of smoke and gusty wind by which they were impelled? The value of the following which was sent by a correspondent to *Nature*, somewhat depends on this question. He reports the following observations on the velocity of the wind in the southwest gale on the 21st, and 22nd of November last, at Edinburgh: "The observations were made about 9 o'clock on the morning of the 22d, when the wind had somewhat moderated: Mean velocity, 62.3 miles per hour; during a squall, 61.6. These observations he calculated from clouds of smoke issuing from the chimney of the Caledonian Distillery, and traveling for a distance of 2108 feet, and are thus free from instrumental errors. The chimney is 225 feet higo, and its base about 200 ft above the sea level. During the gales on the 14th the recording anemometer at the Greenwich observatory registered a wind pressure of 57 pounds per square foot, the highest ever recorded there. Prof. Robert Grant, F. R. S., who occupies the chair of Practical Astronomy in the University of Glasgow, reported that during the violent storm which passed over that city on the night of November 21st, and the following morning, during several hours after the special observations commenced, the velocity of the wind ranged from 16 miles to 17 miles, but at 11 p. m. it had risen to 30 miles, and it went on increasing till 2 o'clock next morning, when the register indicated a velocity of 54 miles an hour, and the reading at 6 o'clock was 57 miles an hour. Just a few minutes before 11 o'clock there was a tremendous gust of wind, which, measured by Osler's anemometer, was equivalent to a wind pressure, as already mentioned, of 48 lbs. on the square foot. This was confirmed by the indications of Robinson's velocity anemometer, which showed that for a few minutes the wind was traveling at the rate of nearly 80 miles an hour.

A New Electric Current Meter—At the Physical Society, on January 28, Mr. C. Vernon Boys read a paper on an apparatus for measuring the strength of an electric current, which, so far as we are aware, is highly original. The rate of a pendulm clock depends on gravity, and is proportional to the square root of the strength of gravity. The rate of a watch depends on the strength of the hair spring, and is proportional to the square root of the hair spring. The force due to a current passing through any combination of wires and iron is proportional to the square of the current strength. If, then, any of the parts of the combination are arranged so that they vibrate under the influence of an electro-magnetic force, the speed of vibration will be simply proportional to the current strength, because the square of the speed measures the force, and the force is proportional to the square of the current. Let such a contrivance take the place of the balance or pendulum of a clock, and the clock will become a measurer of the quantity of electric current instead of time. In order that the indications should be true, either the maintaining power must be so contrived that the amplitude does not vary much, in which case it does not matter what the law is connecting the force with the displacement, or the parts must be so arranged that the force is directly proportional to the displacement, in which case it does not matter what the amplitude is. The two important points, therefore, are the controlling and the maintaining powers. M. Boys showed several ways of producing a controlling power. In the first case, which was a combination of two solenoids, one moving through the interior of the other, the force will, if they are properly arranged, be proportional to the displacement. As there is no iron in this arrangement it will apply to the case of alternating currents. In another case a small armature is mounted on the balance staff, and around it are the two poles of an electro-magnet which forms part of the circuit. Another form is unaffected by residual magnetism. In it two crescent-shaped pieces of iron forming the sides of the balance pass through two fixed solenoids. The iron pieces are carried by a cross arm mounted on a vertical spindle, and they serve to form sectors of a circle like the balance wheel of an English lever watch. By passing the current through the coils, the cores are attracted into the latter, and if the current diminishes or increases in strength, the cores will retire or advance within the coils. In all these cases the direction of the current is of no consequence. The maintaining power may be an ordinary escapement driven by clockwork in the usual way. In this case the amplitude will be less with a stronger current; but this drawback may be overcome by the use of an electro-magnetic *remontoire*. The maintaining power can, however, be independent of clockwork if an impulse is given to the electricity at each swing of the balance. Mr. Boys exhibited a meter constructed on this principle for him by Messrs. Elliot Brothers. The controlling power in it depends on iron crescents mounted like parts of a watch balance wheel on a vertical spindle, and each enclosed by a pair of solenoids consisting of a primary and secondary coil. The main current runs through the primary solenoids, but a portion of it is diverted through the secondary solenoids when the balance is its neutral position, at which time a variation of the current in the controlling solenoids has no effect in disturbing the period of an oscillation. To regulate meters of this class, a weigher is screwed outwards or inwards, according as the meter goes too fast or too slow. As this meter depends on dynamical principles alone, and is independent of gravity, it must work equally well wherever it is planted.

On a recent occasion Dr. Grant, of Glasgow, gave an interesting summary of the present state of the science of meteorology. In the course of his remarks he said:—"The Meteorological Office, originally a branch of the Board of Trade, commenced its labors in 1868, the council of scientific men, under whose direction it is conducted, being nominated by the Royal Society. There are three leading objects which the council have kept in view since 1868. These are:—(1) Ocean Meteorology; (2) land meteorology of the Britis Isles; (3) weather telegraphy. Seven observatories have been established in connection with the Meteorological Office, with a view to the advancement of the land meteorology of the British Isles. These are the observatories of Valentia and Armagh, in Ireland; Falmouth, Kew and Stonyhurst, in England, and, finally, Glasgow and Aberden, in Scotland. The observations at each of these observatories are all obtained by means of self-recording instruments, and the tabulated results are regularly transmitted once a week to the Meteorological Office in London. The variations of the barometer and of the dry and wet bulb thermometers are recorded continuously upon paper by a photographic process which goes on night and day without intermission. The velocity of the wind is measured by Dr. Robinson's anemometers. The mean hourly velocity of the wind for the three years 1874, 5–6 was:—for Armagh, 10.6 miles, 10.0 miles, and 9.8 miles; for Kew, 10.3 miles, 10.8 miles, and 10.8 miles; for Stonyhurst, 10.8 miles, 10.9 miles, and 10 7 miles; for Glasgow, 12.9 miles, 12.9 miles, 12.1 miles, and 12.4 miles; for Aberden, 13.3 miles, 13.5 miles, and 14.2 miles; for Falmouth, 16.8 miles, 17.0 miles, and 17.4 miles; finally, for Valentia, 18.2 miles, 17.7 miles and 17.9 miles. During the last two or three years as many as 75 per cent. of the storm warnings which have emanated from the Meteorological Office have been thoroughly successful. During the storm of Friday, the 6th ult. Osler's anemometers recorded a pressure of 51 lbs. on the square foot, and yet it bore the strain admirably. During the great snowstorm which swept over London and its neighborhood on the 18th January, 1881, the Osler anemometer at the Royal Observatory, Greenwich, registered as high as 51. lbs. on the square foot."

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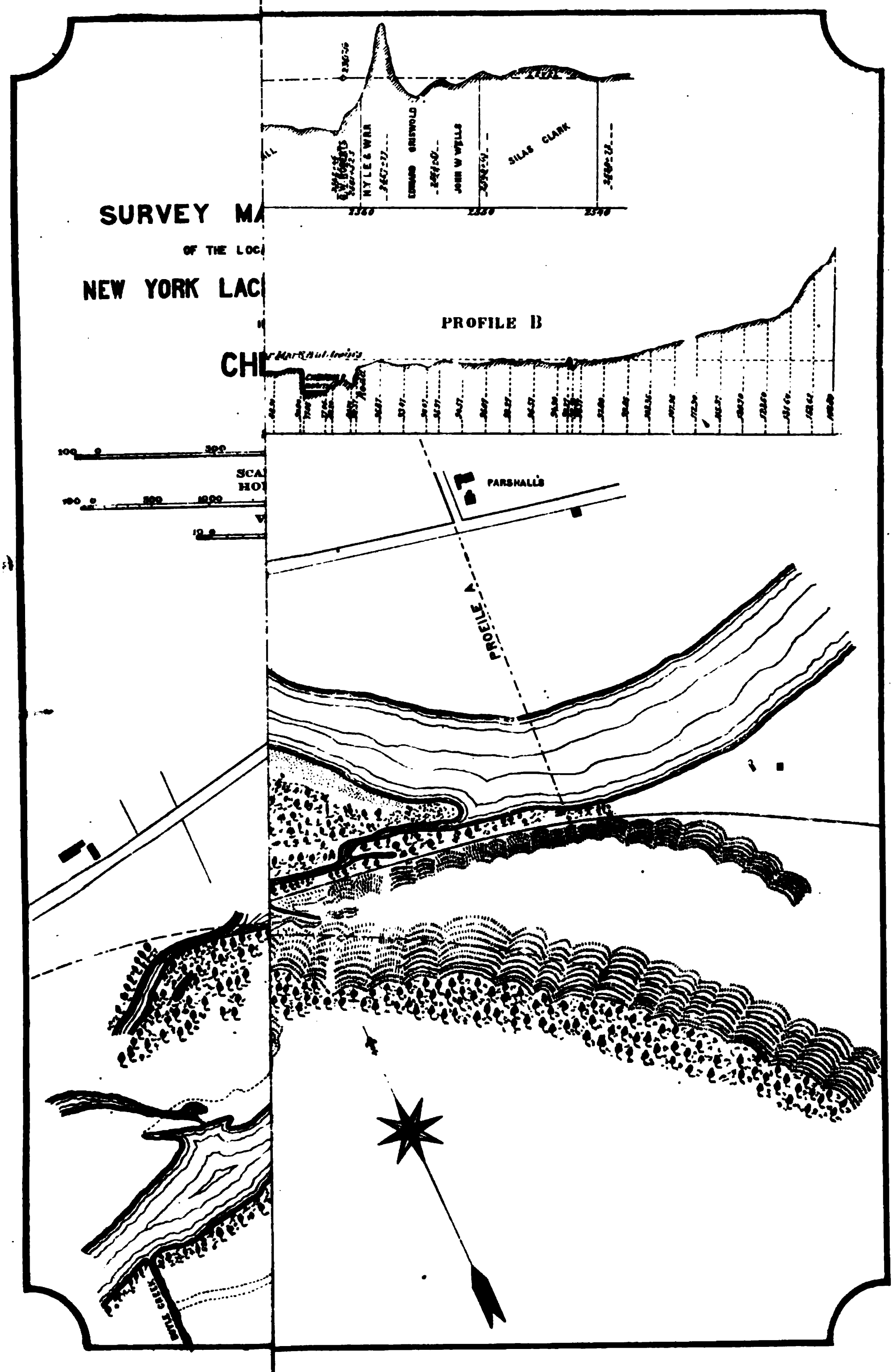
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OBSTRUCTION TO RIVER DISCHARGE BY BRIDGE PIERS.

By Q. A. GILLMORE, Lieut.-Colonel of Engineers, Brevet Major-General, U.S.A.

In 1881 the question of crossing the line of the New York, Lake Erie and Western Railroad by the line of the New York, Lackawanna and Western Railway, then under construction through the town of Chemung, Chemung Co., New York, came before a commission at Elmira, N. Y. (For the sake of brevity these roads will be designated the Erie Railroad, and the Lackawanna Railroad, respectively.)

The place selected for the crossing by the Lackawanna Company is about ten miles east of Elmira. At this point and for some miles west of it, the Erie Railroad skirts the base of the hills on the south side of the Chemung River Valley, while to the eastward its track leaves the high ground and traverses the bottom lands for a distance of about three miles, and then crosses to the north side of the Chemung River.

The entire width of the valley, including the flats on both sides, subject to overflow in times of freshet or flood, varies from one-half to three-fourths of a mile, and within this width the river, while pursuing its southeasterly course toward the Susquehanna, of which it is a tributary, meanders from side to side, in the manner usual with streams flowing through alluvial lands. The bed of the stream as defined by its banks at ordinary stages, has a width ranging from 400 to 500 feet, and the banks themselves are ten to fourteen feet in height above the ordinary low river-stage. The surface of the bottom lands is somewhat undulating and irregular, so that a flood rise of twenty feet above extreme low river overflows them to a depth varying from four to ten feet, the average depth being not more than five and a half feet. With a flood of this height, which is not of frequent occurrence, the width of the river at Baldwin's, opposite the point where the railroads cross each other, is 3900 feet. Half a mile below this point, that is to the eastward at Parshall's, the flood width is 3200 feet, and half a mile to the westward it is about 4000 feet; but on this westerly section the highway near the bank of the stream, on the north side, is not put under water by a twenty foot rise, although the bottom land between it and the high ground to the northward is submerged to the depth of six feet in some places. The sections at Parshall's and Baldwin's are given at profile A and profile B respectively, on the map.

The average of the three widths given above, or 3700 feet, $\left(\frac{3200+3900+4000}{3}\right)$ may be fairly assumed as the mean width of the stream during a twenty foot rise, on the reach about one mile in length above Parshall's.

It is in evidence that a flood of this height occurred in March, 1865, and maintained its highest level for several hours, submerging the Erie track to the depth of the floor of a hand car, and causing an entire suspension of traffic on that part of the road.

The river at the point of crossing drains an area of about 3000 square miles, and at ordinary low stage is an insignificant stream, in some places not more than 100 feet wide, consisting of a succession of ripples and slackwater pools, the general slope, as ascertained by precise levels, being four feet to the mile. The depths in the pools vary from four to ten feet. The low river discharge probably does not exceed 3000, possibly not 2500 cubic feet per second.

The track of the Erie Railroad, in the vicinity of the crossing, and for some miles on either side of it, has an easterly descending grade varying from five feet to seven feet to the mile. Its general height above the low-river surface is from seventeen and a half to eighteen feet, and above the general level of the bottom lands about three and a half to four feet on the average.

A narrow branch of the river, or more properly speaking perhaps, a slough or cove known as Parshall's Cove, about as deep as the main stream, runs in close proximity and nearly parallel to the track of the Erie Railroad at the point of crossing, and to the east and west of it, for a distance of fully three-fourths of a mile, thus separating it from the bottom lands.

During the flood stage, when the flats are under water, this slough runs with a high velocity and discharges a comparatively large volume of water. At ordinary stages however when the river is not over its banks, the upper end of this cove has no connection with the main stream, the water in it being stagnant, and entering mostly from below, where the connection is kept up even during the low-river stage.

The Lackawanna Road approaching from the east, as projected, crosses the Erie Road above grade at an acute angle of twenty-six degrees, then crosses Parshall's Cove at the same angle on a bridge of three spans of 150 feet each, measured parallel to the track, giving an effective aggregate opening of only 180 feet at right angles to the axis of the Cove, then crosses the bottom lands diagonally with a descending grade of 13.728 feet per mile, on a solid embankment, for a distance of about 3300 feet to the right bank of the Chemung River, crossing that river at an angle of about seventy-eight degrees with the direction of the current, on a bridge of four spans, each of 150 feet clear opening, equivalent to an effective opening at right angles to the stream of 576 feet. From the abutment on the left bank, the Lackawanna Road, as projected, continues on a solid embankment to the high ground on the north side of the valley.

The line of flood level on the sections taken at Parshall's and Baldwin's, profile A and profile B, is that of the flood of 1865. Adopting 3700 feet as the average width at the flood stage of these two sections and the one-half a mile above Baldwin's, it will be seen that the Lackawanna Railroad, as projected, leaves an effective opening in their construction across the valley, from the high land on one side to the high land on the other, of only 756 feet (180+576), thus actually reducing the width of the high river water way nearly eighty per cent.; that is, the obstruction consisting of embankment and bridge piers and abutments, would amount to nearly four-fifths of the entire width pertaining to a flood like that of 1865.

The effective water way, however, would not be obstructed in nearly so great a proportion, because the bridge openings are located in the deepest water. By measuring the area of the three flood sections referred to above, we obtain 31,538 square feet as the mean sectional area $\left(\frac{24235+27294+43085}{3}\right)$. The flood area under the bridges on sections taken at right angles to the thread of the current is 13,068 square feet. The effective water way for a twenty-foot rise, like that of 1865, would therefore be obstructed $58\frac{6}{10}$ per cent. by the Lackawanna Road, as projected, provided we assume that the proper way to measure the clear or effective water way in oblique crossings, is at right angles to the thread of the current and the faces of the piers.

The Erie Road opposed the location

and method of construction adopted by the Lackawanna Road for crossing the Valley, on the ground that so serious an obstruction to the passage of the floods would cause an increased rise or banking-up of the water to such a degree that the destructive effects of the higher floods would be greatly increased, while those of ordinary magnitude, which would otherwise be harmless, might thereby be rendered dangerous and destructive. It was also claimed that there would be danger from ice gorges, and that the funnel shaped opening between the two tracks, above their intersection, with its base pointing up stream, rendered the accumulation of ice and the formation of an ice gorge at the Cove bridge highly probable.

During the trial before the Commissioners, professional engineers were placed upon the witness stand by both parties.

As there had been no extraordinary flood in the river since the question of crossing first arose between the two Companies, and as there had been no observations of a scientific character made of the flood of 1865, or of any flood indeed, it was found that there was not much positive knowledge available, concerning the behavior of the river in times of bank overflow, more especially its slope, mean and bottom velocities, and discharge, upon which a perfectly satisfactory professional opinion could be based. There was however considerable information among the older residents of the locality bearing more or less directly upon the question at issue, and there was one important item of precise knowledge which gave the extreme height of the flood of 1865 at two points near the highway on the north bank. One of those marks was made by Mr. Parshall after the water had reached its highest stand, upon the brick wall of the house in which he lived. The mark, with the date of the flood, is perfectly distinct at the present time, and the wall itself is stained by the turbid water as high as submerged, showing a sharp and well defined flood line. Distinct flood marks are seen at other points on Mr. Parshall's premises to the identity of which with the flood of 1865 he bears testimony.

At a distance of 2400 feet up stream from Parshall's the flood line of 1865 was marked by Mark Baldwin, on a large tree standing on the roadside near his house. The mark was made with an axe and is quite plain at the present time, and as Mr. Baldwin, who is now living, asserts its genuineness, there seems to be no occasion for doubt on this point. A straight line drawn through this tree at right angles to the direction of the stream will intersect the Lackawanna line near the western abutment of the Erie bridge.

The difference of level between the flood marks at Parshall's and Baldwin's is 1.73 feet which determines the surface slope of that flood to have been 3.806 feet per mile, or .0007208. This was on the flat where the water was shallow. The slope could not have been less than this in the main stream. On the contrary it would naturally be expected that the flood slope would be at least as steep as that of low river which is four feet to the mile, and certainly as steep as that of the overflowed bottom lands of the Valley, on the line of its general axis, which is known to be more than four feet to the mile.

Discharge.—The calculations for discharge will be applied to the profile at Parshall's house as determined by the flood of 1865, the width of water way being 3200 feet and its area 24,235 square feet, and the ascertained slope of 3.806 feet per mile will be regarded as existing at this profile, although strictly speaking, it belongs to the length of 2400 feet between Parshall's and Baldwin's.

This profile may properly be divided into two compartments, viz; a deep compartment embracing the bed of the Chemung River, and a shallow compartment covering the flats inundated during that flood.

The following quantities are known.

	Width.	Area	Hydra'lic Radius.
Deep Compartment.	500 ft.	10,752 sq. ft.	21.504 ft.
Shallow Compartment. ...	2700 "	13,483 " "	4.9937 "
Total....	3200 "	24,235 " "	

Surface Slope=.0007208

The hydraulic radius should be obtained by dividing the area of the profile by the length of wetted perimeter. In the present case that perimeter is so nearly identical in length with the width, that the latter is used to determine the value of the radius.

To find the volume of discharge, the

mean velocity with which the water flows through a given area of cross section must be known. Various formulas for this purpose have been constructed by scientists, some of them being simple in form, while others are more or less complicated. All of them so far as known require the slope of the water surface to be given, and also, directly or indirectly, the hydraulic radius.

One of the most simple of these formulas is that of D'Aubuisson, rendered into English measure by Downing. If

v=mean velocity in feet per second
R=hydraulic radius in feet, and
S=slope of water surface, then

$$v=C\times\sqrt{R\times S}$$

Using the values given above for the two compartments, the following results are obtained by means of the Downing formula, assuming the co-efficient C equal to 100 in the bed of the stream, and 84.3 according to Young, in the shallow compartment on the flats.

	Mean Velocity	Volume of Discharge
In the Deep Compartment	12.4500 ft.	133,865 cub. ft.
In the Shallow Compartment	5.0577 "	68,194 " "
Total Discharge		202,059 " "

$$\text{Mean Velocity}=\frac{202{,}059}{24{,}235}=8.3 \text{ feet per second.}$$

Among the foregoing deductions both the mean velocity in the deep compartment, and the aggregate volume of discharge attract attention by their magnitude. It will naturally be asked will the Chemung River, which is an insignificant stream in times of ordinary dry weather, flow with a mean velocity of 5.7 miles per hour, and discharge two hundred thousand cubic feet of water per second during a twenty-foot rise, equal to one-fifth the flood discharge of the Mississippi at New Orleans?

With regard to the volume of discharge it may be said that at the time of the rise referred to, the ground was frozen, and was covered with a heavy layer of snow. The weather suddenly became quite mild, and the snow began to melt rapidly, and this melting was accelerated and the flood was increased by a heavy fall of rain. For a few hours the volume of water carried into the stream was comparatively very large. Indeed if the volume which reached the stream during each of the four hours while the maximum height was maintained, amounted to one-tenth of an inch, or to be precise, to one hundred and four thousandths ($\frac{104}{1000}$) of an inch in depth over the whole area of water shed, it would account for the entire calculated discharge of 202,059 cubic feet per second. There would therefore seem to be no difficulty in regarding this as the actual discharge while that flood was at its maximum height, and as likely to occur at any time under a similar combination of circumstances.

In comparing the Chemung River with the Mississippi it should be remembered that although the flood section of the former is only about one-eighth that of the latter, its surface slope, on which the velocity and therefore the volume of discharge directly and largely depend, is about thirty-five times as great.

With regard to the computed mean velocity of 12.45 feet per second, or nearly 8.5 miles per hour in the bed of the stream, corresponding to a bottom velocity of 7.7 to eight feet per second, it may safely be said, from an examination of the tailings of bars and shoals, and from the statements of men who have resided on the banks of the Chemung River for many years, that large rounded stones of various shapes and sizes, very many of them weighing as much as thirty to fifty pounds, and measuring from eight and a half to ten inches in diameter, are carried down stream by floods of less magnitude than that of 1865. It is well known that they are moved more or less whenever the stream runs bank-full or nearly so.

This point although not discussed at any length in the testimony before the Commissioners, seems to be well established. These stones are not merely left in their places by the washing out and removal of the finer materials, they are positively moved more or less by every high freshet, as shown by the circumstance that the tailings are lengthened by extension down stream from year to year, the comparisons being made at the same stages of low river in successive seasons. On occasions of high freshet the stream becomes a not very mild type of mountain torrent.

The question in this connection is, What bottom velocity is necessary to transport rounded stones of from thirty to fifty pounds weight ranging from eight to ten inches in diameter?

It is believed that the following observations, even if they fail to convey any new information or develop any new facts, will at least show that our present knowledge on this subject is not only meager in amount but unsatisfactory and inconclusive in character.

MOVEMENT OF STONES IN RIVER BEDS.

The various rules or formulas referring to the motion and effects of flowing water, in river beds, are merely approximations in the matter of general application. Some of the more modern formulas seem to give results that agree more closely with observed facts than the older ones, so far as the mean velocity is concerned, but the determination of bottom velocities and of the weight and size of gravel, shingle and stones moved along the river bed by the bottom currents, are still matters of much doubt. In rivers of considerable depth it is generally impracticable to get stationary current meters sufficiently near to the bottom to give the real bottom velocities, and river reaches of even a few hundred feet in length will rarely be found of such uniform longitudinal section, that submerged floats will throughout the whole length pass close to the bed of the stream.

It is probable also that the bottom velocity varies greatly with the depth, although the mean velocity may remain nearly the same. The larger volume of water passing through a deep profile may flow with a more uniform motion, or with less marked differences between maximum and minimum velocities, than through a shallow profile. The current observations on the Mississippi River, have, in a number of cases, even shown the greatest velocity to be at, or near the bottom.

Generally speaking, engineers assume that the bottom velocity is less than the mean. A few rules have been applied to determine approximately the bottom velocities that may have existed in the Chemung River during the high flood of 1865.

1. Prony gives a formula which rendered into English terms, reads

$$\frac{m}{v}=\frac{v+7.71}{v+10.28}$$

in which m=mean velocity in feet per second.

and v=surface velocity in feet per second.

We deduce from this the surface velocity to be

$$v=\frac{m-7.71}{2}+\sqrt{\left(\frac{m^2}{4}+6.425\times m+14.86\right)}.$$

According to Rankine the bottom velocity can be assumed to be as much less than the mean velocity, as the maximum or surface velocity is greater than the mean. Therefore, if b represents the bottom velocity, we have $b=2m-v$.

According to this rule, the maximum velocity in the deep compartment in which the mean velocity was computed to be 12.45 feet per second, would be 13.9 feet, and the bottom velocity about eleven feet per second, or 7.5 statute miles per hour.

In the deepest portion, where there is nearly or quite 24 feet depth of water, the mean velocity is computed at about 13 feet, corresponding, by the rule, to a bottom velocity of 11.5 feet, or 7.84 miles per hour.

2. Du Buat's formulas, are as follows: Let

a=the observed surface velocity,

b=the bottom velocity,

c=the mean velocity; all in inches per second,

then

$$a=\left(\frac{1}{2}+\sqrt{C-\frac{1}{4}}\right)^2$$

$$b=(\sqrt{a}-1)^2$$

$$c=\frac{a+b}{2}$$

With an average velocity of 12.45 feet per second in the deep compartment, the above rule gives a bottom velocity of 11.4 feet or 7.77 miles per hour; or nearly 12 feet per second, equal to 8.15 miles per hour in the deepest portions.

3. In Trautwine's Civil Engineers' Pocket Book 1872, pp. 562 and 563, the following rule is given to find approximately the velocity at the bottom of a stream:

Rule: Multiply surface velocity by a certain coefficient given in table 15 to find the mean velocity. Multiply this mean velocity by 2. From the product subtract the surface velocity; the remainder will be approximately the bottom velocity.

If we express the rule algebraically, let

V_s = surface velocity,
V_m = mean "
V_b = bottom "
x = variable coefficient; then

$$v_s = \frac{v_m}{x}; \text{ and}$$

$$v_b = 2 \times v_m - \frac{v_m}{x} = v_m \times \left(\frac{2x-1}{x}\right)$$

Applying the above rule, we find for the deep compartment a surface velocity of 14 feet, and a bottom velocity equal to 9.09 feet per second, or 6.2 miles per hour. In the deepest part of the section there should be found a bottom velocity of 11.55 feet per second, or 7.87 miles per hour.

4. G. Hagen, from his investigations, thinks that the mean velocity may generally be found actually to exist at about $\frac{4}{9}$ of the whole depth above the bottom of a river. He develops a formula for the mean velocity which is materially different from others, inasmuch as he introduces the 6th root of the slope.

If V = mean velocity in feet per second,
R = hydraulic radius (or mean depth approximately),
S = slope;

his rule, in English terms, is

$$V = 4.39 \times \sqrt{R} \times \sqrt[6]{S}$$

His velocity curve, in a perpendicular, is a parabola, with the vertex at the bottom of the river.

If C = bottom velocity, and
p = parameter of the parabola,

then he finds $\sqrt{p} = 0.225 \times C$;

$$V = C + \tfrac{2}{3}\sqrt{p} \times \sqrt{R};$$

$$\text{and } C = \frac{v}{1 + 0.15 \times \sqrt{R}}.$$

In applying the last rule to the case of the Chemung river, less values are obtained than by the previous methods. For the deep compartment, with a mean velocity of 12.45 feet per second, the bottom velocity is computed at 7.37 feet per second, or 5 miles per hour, and in the deepest portion a bottom velocity of 7.5 feet per second, or 5.11 miles per hour.

5. It is thought that the preceding rules, with the exception of that of Hagen, give excessive values for bottom velocities. If they had existed during such a flood as that of the Chemung river in 1865, they would have been more destructive than they were. Probably, nothing but a rock bottom could have resisted such currents.

The numerous and carefully-conducted current observations made in the Connecticut river by Gen. T. G. Ellis, under direction of Gen. G. K. Warren, U. S. Engineers, described in detail in the annual reports of the Chief of Engineers, U.S.A., for the years 1875 and 1878, show as an average result of all meter and float observations, for various velocities, a proportion of mean to bottom velocity of 193 to 100. Exactly the same result was obtained by current observations made about ten years ago on the river Elbe, in Bohemia, a brief record of which is given in the June number of VAN NOSTRAND'S ECLECTIC MAGAZINE for 1877.

As an average of velocities higher than 1.86 feet per second, the experiments with submerged floats on the Connecticut river showed the bottom velocity to be about 62 per centum of the mean.

Adopting the latter ratio, and it is found that the average bottom velocity in the deep compartment of the Chemung river would have been 7.72 feet per second, or 5.26 miles per hour, and in the deepest portion 8.06 feet per second, or 5.5 miles per hour.

Theoretically, the force of the impact of currents upon loose material obstructing the flow of water is proportional to the square of the velocity of these currents. The resistance of stones of the same kind, of approximately regular shape, spherical or cubes, is in proportion to their weights in water, or as the cubes of their diameter or sides.

If V, v are the velocities of currents, and and W, w the submerged weights of stones, the resistance of which will just be overcome by those currents, then

$$V^2 : v^2 = W : w.$$

If these stones are of similar and somewhat regular form their weights will be as the cubes of similar dimensions D, d;

i.e., of their diameters when round, and of their sides when cubes, therefore

$$V^2 : v^2 = D^3 : d^3.$$

The size and weight of a stone of certain form being known, that will just be moved from its place by currents of known velocity, the above rules would furnish the means of computing the size and weight of a stone of the same specific gravity and form, that would be moved by a different velocity. The data, however, on which to base calculations of that kind are exceedingly restricted in number, and are in some degree contradictory.

Almost every work on Hydraulics refers to Du Buat, who made a number of experiments on a small scale, from which it is believed to be unsafe to make deductions concerning phenomena developed by the currents of a large stream, upon a bed of material varying greatly in size, form and specific gravity. The following abbreviated table, taken from Rankine's Manual of Civil Engineering, shows the greatest velocities of currents close to the bottom, consistent with the stability of various material (according to Du Buat):

1. Gravel, 1 inch in diameter............2.25 feet per second.
2. Pebbles, 1½ inch in diameter..............3.33 feet per second.
3. Heavy Shingle.......4.00 feet per second.
4. Soft Rock, Brick and Earthenware........4.50 feet per second.
5. Rock, various kinds..6.00 feet and upwards

The greatest bottom velocity in the Chemung river (12 feet per second) was computed according to Du Buat's formula (No. 2). A round flint pebble of 1½ inch diameter and 2.6 specific gravity, weighs in water about $\frac{1}{10}$ pound. According to the rule currents flowing with a velocity of 12 feet per second, or 8.15 miles per hour would scarcely be able to set in motion a rounded stone a little over 2½ inches diameter, weighing 1⅛ lbs. in water and 2½ pounds in air. It is well known, however, that currents of less strength do move far heavier stones; and it is evident that Du Buat's table is of little use as a basis for calculations involving velocities greater than a few feet per second.

Beardmore gives the following table:

Velocity of 6 inches per second does not disturb clay, with sand and stone;
Velocity of 8 inches per second moves coarse sand;
Velocity of 1 foot per second moves fine gravel, size of peas;
Velocity of 2 feet per second moves 1-inch rounded pebbles;
Velocity of 3 feet per second moves angular stones about 1½ inch diameter.

Assuming in the last-named case, the stone, moved by a velocity of 3 feet per second, to be of approximately cubical shape, its weight would be about ½ pound in air and $\frac{31}{100}$ pound in water. By the theoretical rule cited above, a maximum bottom velocity of 12 feet per second would only be able to set in motion a cubical stone measuring 4.4 inches on each side, weighing a little over 8 pounds in air and about 5 pounds in water. This result is considered to be still far below what would be the actual fact with such an excessive velocity, as long as the stones are practically isolated from each other, so as to derive no support and increased resistance from being together in large masses and in close juxtaposition.

More recent observations of the power of currents to move stones are briefly recorded in the report of Engineer-in-Chief Jaquet on the improvement of the River Rhone from Lyons to the sea, dated July 1, 1878. He states that Chief Engineer Sainjon found that in the River Loire gravel and stone were moved as follows (here expressed in English terms of weights and measures):

Velocities in feet per second, 1.64, 3.28, 4.92, 6.56.
Diameters of stones in inches, .40 1.60, 3.90, 6.70

This little table substantially agrees with the formula expressing resistances of surfaces and bodies under water, originally, it is thought, given by D'Aubuisson, to wit:

$$R = C \times \frac{v^2}{2g} \times A \times w, \text{ in which}$$

R = resistance of the body to motion,
v = velocity in feet per second,
g = force of gravity at the place,
A = area of cross section of the body in square feet,
w = weight of a cubic foot in water,
C = coefficient, supposed to be constant for the same form of solid, but varying for different forms.

The resistance therefore varies as the square of the velocity; and with equal velocities, as the area of cross section.

Instead of $\frac{w}{2g}$ we use the co-efficient, $971\left(=\frac{62.5}{64.36}\right)$; therefore, $R=.971\times C\times a\times v^2$.

For a square plate, C is said to be equal to 1.43; for a cube, 1.21. To determine its value for a sphere (rounded stone) we assume that Sainjon's statement is correct: *i.e.*, that a stone of 6.7 inches diameter is moved by a velocity of 6.56 feet per second.

On this basis we have C=.8896.

It has been already suggested that the bottom velocities found by the older formulas are too large. It is deemed to be much more within the limits of probability to adopt the results based on the experience lately had on the Connecticut River.

We find then that with a bottom velocity of 7.72 feet per second, stones of 9½ inches diameter, and weighing thirty-nine lbs., may be moved; and with a maximum velocity of 8.06 feet in the most rapid places, the moving stones may weigh as much as 51lbs.

The preceding calculation of sizes and weight of stones, liable to be moved by the bottom currents during high floods, are based upon the velocities found by the D'Aubuisson-Downing rule. To compare results, velocities found by a few other formulas will now be used for computation.

By Darcy-Bazin's formula, the average velocity in the deep compartment was determined to be 12.35 feet per second, 62 per cent. of which, or 7.66 feet, would be the average bottom velocity. In the deepest places, with 24 feet of water, the mean velocity in the vertical plane would be 13.15 feet, with a bottom velocity of 8.15 feet. (For a depth of 24 feet, Darcy-Bazin's co-efficient for $\sqrt{R\times S}$ is a trifle over 100.

These bottom velocities would probably move stones measuring 9½ to 10½ inches diameter, weighing from 37 to 53 lbs. respectively.

By the Mississippi formula of Humphreys and Abbot, the average velocity in the deep compartment of the river was found to be 7.733 feet, supposed to correspond to a bottom velocity of 4.79 feet, which would be able to move stones of $3\frac{9}{16}$ inches diameter, weighing 1.37 pound. The velocity in the deepest section, at the bottom, would be 5.09 feet, capable of moving round stones of 4 inches diameter, and 3¼ lbs. weight.

According to the formula of Gauquillet and Kutter, the general average velocity in the deep compartment of the Chemung, would be 10.0122 feet per second, with a probable bottom velocity of 6.2 feet. In the deepest part, the mean velocity is computed to be 12.2 feet, and 7.56 feet at the bottom. These bottom velocities may move stones of from 6 to 8⅞ inches diameter, weighing from 10½ to 34 pounds.

From the foregoing, it appears that the movement of rounded stones in the bed of the Chemung River, measuring from 8½ to 10 inches in diameter, and weighing from 30 to 50 lbs. is entirely consistent with the calculated discharge of 133.865 cubic feet per second, in the deep compartment of the stream, and the bottom velocities corresponding thereto.

It has been observed upon the Mississippi and Missouri Rivers that at the moment when the rising water overflows the banks and spreads over the bottom lands there is a reduction of velocity in the bed of the stream. A deposition of silt, and a building up of the bottom is the natural result of such action. The water from the bottoms flows into the stream at sundry places, bringing large quantities of silt with it. The same phenomena was probably developed in the Chemung River, the bottom being covered, for a time, with a layer of comparatively small gravel and pebbles, which were removed when the water subsided to the height of the banks. If so, the larger stones would be protected by a covering of smaller materials during the period of bank overflow, moving only while the water was within the banks, both on the rising and the falling stage.

INCREASED HEAD OR BANKING UP OF THE WATER.

To make an approximate computation of the head, probably produced by confining the water-way to the openings afforded by the two proposed Lackawanna bridges, it is assumed that these structures are located in an average profile of 3700 feet width, and 31,538 square feet area of cross section. In other words, for purposes of computation the Lackawanna Railroad is assumed to cross on a line of embankment and bridges located at right angles to the axis of the Valley, with a clear opening of 756 feet.

The average velocity of the water flowing through this average or imaginary profile during the highest flood, would be

$$v=6.4 \text{ feet per second, } \left(\frac{202,059}{31,538}\right)$$

The average hydraulic radius of this profile would be 8.5238 feet$\left(\text{or } \frac{31,538}{3700}\right)$

As to the reduced area of water way, an inspection of the flood profiles of the openings afforded by the two bridges has given the following approximate data:

	Effective width.	Area.	Hydra'lic Radius.
	feet.	sq. ft.	feet.
Chemung bridge.	576	9,868	17.132
Cove bridge.....	180	3,200	17.770

The difference between the two radii is so small that a common radius or mean depth for both bridge openings may be assumed without material error. The radius or mean depth at both bridges will therefore be taken at 17.2857 feet, $\left(\frac{9868+3.200}{576+180}\right)$

Works on hydraulics give different formulas for determining the amount of head produced in front of bridges and similar obstructions. Eytelwein gives the following:

$$y=\frac{v^2}{m^2}\times\left(\frac{W^2\times h^2}{w^2(h+y)^2}-1\right):$$

in which, v=mean velocity in original profile, in feet per second.

y=Increased head or banking up, in feet;

W=original width of profile, in feet;

w=reduced width of profile, in feet;

h=original mean depth of profile, in feet;

$\frac{1}{m^2}$=coefficient for contraction.

It is stated that where the contraction is produced by bridge piers, experience has shown that $\frac{1}{m^2}$ is about equal to 0.017, and this value will be used, although in the case before us the construction is the result of a combination of piers and solid embankments.

To apply the formula to the present case, the term h, in the denominator must be changed to h_1, representing the greater mean depth existing under the bridges, these having been located over the low river water ways, and where, therefore, by far the greatest depths are found at the flood stages.

The modified formula reads then:

$$y=\frac{v^2}{m^2}\times\left(\frac{W^2\times h^2}{w^2\times(h_1+y)^2}-1\right)$$

v=6.4065 feet,
W=3700 feet,
w=756 feet,
h=8.5238 feet,
h_1=17.2857 feet,
$\frac{1}{m^2}$=0.017 feet.

We find y=2.4272 feet . . . . (1).

How far up the stream the banking up of water caused by the bridges may extend, cannot be determined with accuracy, not only because the configuration of the flood-bed is imperfectly known, but also because the whole question has not yet been satisfactorily settled in theory. For common river courses of nearly uniform cross-section, D'Aubuisson says that the rise of water above the original slope-line will be sensibly felt to a distance up stream expressed by the equation:

$$D=1.9\times\frac{y}{s}$$

in which D=distance in feet,
y=head at obstruction in feet,
s=original slope.

If we assume that the slope above the profile is the same as between Baldwin's and Parshall's, then the distance will be 6398 feet or 1.21 miles.

Another solution of the problem of the amount of head formed at bridges is given in A. Debauves' *Manuel de l'In-*

genieur des ponts et Chaussies, 10*d Fascicule, ponts en Maconnerie.*

The formula is as follows:

$$y=\frac{Q^2}{2g}\times\left(\frac{1}{m^2\times w^2\times h^2}-\frac{1}{W^2\times(h+y)^2}\right)$$

In this formula, m is a co-efficient for contraction which has the following values, according to Gauthey:

$m=0.95$ when the piers present an acute angle to the current;
$m=0.90$ when the piers are rounded off to a demi-circle;
$m=0.85$ when the piers have square heads;
$m=0.70$ when the pier arches are small and more or less submerged.

The other terms represent the following values:

Q=volume of discharge, in cubic feet, per second.
$2g=64.36$ or double the acceleration of falling bodies at the end of 1st second.
W=original width of profile, in feet;
w=reduced width of profile, in feet;
h=mean depth of original profile, in feet;
y=increased head or rise in feet.

To apply this formula to our case, h in the first member or fraction must be changed as before to h_1, representing the greater depth under the two bridges. We then have

$$y=\frac{Q^2}{2g}\times\left(\frac{1}{m^2\times w^2\times h_1^2}-\frac{I}{W^2\times(h+y)^2}\right)$$

$Q=202{,}059$ cubic feet,
$W=3700$ feet,
$w=756$ feet,
$h=8.5238$ feet,
$h_1=17.2857$ feet,
$m=0.9$.

We get $y=4.3168$ feet=increased head at bridges . . . . (2).

$$D=11{,}378\text{ feet}\left(=\frac{1.9\times4.3168}{.0007208}\right)$$

=2.16 miles, the distance above the obstruction at which the increased rise will cease to be felt.

ADDITIONAL CALCULATIONS.

In the foregoing calculations, Downing's formula for determining the mean velocity was used to obtain the discharge. For comparison, three other formulas will now be tried, namely that of Bazin, then the Humphreys-Abbot or Missisippi formula, and finally that of Gauquillet and Kutter.

BAZIN'S FORMULA FOR VELOCITIES.

For river beds in their natural condition, the value v (velocity in feet per second) expressed in English terms of measure, is as follows:

$$v=\frac{\sqrt{R\times S}}{v\left\{.00008534\times\left(1+\frac{4.1013}{R}\right)\right\}}$$

R=hydraulic radius in feet,
S=slope.

Applying this formula to the profile at Parshall's, we have

In the deep compartment $v=12.3503$ ft.;
volume . . . . =132,790 cub. ft.
In the shallow compartment $v=4.8122$ ft.;
volume . . . . = 64,883 "

Total volume of discharge per second=197,673 "

With a volume of 197,673 cubic feet, we obtain:

3. *Increasec rise in feet*, by Eytelwein's rule, $y=2.3474$ feet.

Extension of rise, up stream, D= 6.187 feet (=1.17 mile.)

4. *Increased rise in feet*, by Debauve's rule, $y=4.1113$ feet.

Extension of rise, up stream, D= 10,837 feet (=2.05 mile.)

Humphreys and Abbot's formula, in its most simple form (see page 29, notes on practical gauging of rivers No. 2 printed papers, by Gen. H. L. Abbot, April 13, 1868,) gives the following equation for velocity v.

$$v=\left\{\sqrt{m+\left(\frac{225\times a\times\sqrt{S}}{p+W}\right)^{\frac{1}{2}}}-\sqrt{m}\right\}^2$$

m=co-efficient varying with the hydraulic radius;
a=area of cross section, in square feet;
S=slope;
W=width at water surface;
p=wetted perimenter (approximately equal to $1.015\times W$,)

For the profile at Parshall's we get:

	Radius.	m.	$\sqrt{m}$.	Area.	W.	p.	Velocity.	Volume.
	feet.			sq. ft.	ft.	feet.	feet.	Cub. feet
Deep compartment	21.5040	.002825	.0531	10,752	500	507.5	7.7330	83,150
Shallow compartment	4.9937	.005400	.0733	13,483	2700	2740.5	3.5914	48,423
Total								131,573

With this aggregate volume of 131,573 cubic feet we obtain

5. *Increased rise in feet*, by rule in Eytelwein's work, $y=1.2092$ feet.

Extension of rise, up stream, D= 3,187 feet ($\frac{6}{10}$ mile.)

6. *Increased rise in feet*, by rule in Debauve's work, $y=1.7587$ feet.

Extension of increased rise up stream, D=4,636 feet (or $\frac{7}{8}$-mile.)

The rule for determining the mean velocity of water in rivers, given by *Gauquillet and Kutter* for Austrian measures, is as follows:

$$v=\left\{\frac{41+\frac{1.779}{n}+\frac{.00276}{s}}{1+\left(41+\frac{.00276}{s}\right)\times\frac{n}{\sqrt{R}}}\right\}\times\sqrt{R\times S}$$

S=slope of water surface;
R=hydraulic radius;
$n=.026$ for large rivers.

In using this formula it must be remembered that 1 ft. Austrian=1.0371 ft. English.

For the profile at Parshall's, we obtain:

Deep compartment, velocity=10.0122 feet;
volume . . . . =107,650 cub ft.
Shallow compartment, velocity=3.9576 feet;
volume . . . . = 53,360 "

Total volume . . 161,010 "

7. *Increased rise in feet*, by rule in Eytelwein's work, $y=1$ 6968 feet.

Extension of increased rise up stream, D=4,472 feet, =.847 mile.

8. *Increased rise in feet*, by rule in Debauve's work, $y=2.6775$ feet.

Extension of increased rise up stream, D=7,057 feet=1.337 mile.

RECAPITULATION.

Formulæ for velocity.	Volume of discharge.	Formulæ for rise. Eytelwein.	Formulæ for rise. Debauve.
		feet.	feet.
Downing	202,059	2.4272	4.3168
Bazin	197,673	2.3474	4.1118
Humphreys-Abbot	131,573	1.2092	1.7587
Gauquillet and Kutter	161,010	1.6968	2.6775

The widely varying results obtained by using different formulas for discharge and for banking up, as shown in the foregoing discussion, afford a striking proof of the imperfection of our knowledge on this subject, and the danger of placing too much reliance upon conclusions drawn from the application of fixed rules to the phenomena of river flow.

The inherent value of an empirical rule depends not only upon the degree of care with which the fundamental observations are made, but upon the intelligence with which those observations are interpreted.

Hydraulic formulas probably have a somewhat restricted range, and the local conditions under which they are applied in practice should differ as little as possible from those upon which they were originally constructed.

The depth of a stream, the longitudinal and transverse profiles, the surface slope, the tortuosity, the ratio of friction to volume of discharge and the character of the bed and banks, are all widely varying functions in different parts of the same stream, even while the water remains at a fixed stage. And it will perhaps be conceded, that a formula which shall satisfactorily express these complex conditions—supposing such a formula possible—may become inapplicable to a greater or less degree, when we pass to other streams, whether larger or smaller, or to higher and lower stages of the same stream.

The results of the trial, as recommended by the Commissioners and adopted by the Justice of the Supreme Court of the State in rendering his decision, are briefly as follows:

1st. The Lackawanna track shall cross the Erie track at a clear height of 20 feet above the latter, on a through bridge of 55 feet clear span, measured at right angles to the tangent to the Erie curve at the point of crossing.

2d. The bridge over Parshall's Cove, the solid embankment from said bridge to the south bank of the Chemung River, and the bridge over said river may be constructed as projected by the Lackawanna Company, while west of the western abutment of the Chemung bridge for a distance of 405 feet, bridging shall be constructed in spans of not less than 135 feet. The height of the bridging at the Cove, at the Chemung River and westerly therefrom shall be not less than 20 feet above the low water of the river.

3d. The material under all the bridge spans, except that over the Erie track, is to be excavated to the level of low water.

The court awarded the sum of fifteen hundred and one dollars to the Erie Railroad Company, to be paid by the Lackawanna Company, such being the amount of the damages to the first-named company as estimated by the Commissioners.

Of the above sum, one dollar was to be paid for the use of the Erie Company's right of way at the point of crossing; $500, as compensation to that Company for necessary expenses in taking certain precautions while the bridge spanning its tracks is in course of construction; and the sum of $1000 for expenses to be incurred by the Erie Company by being obliged to rip-rap the side slope of its road at and near the crossing, as the Commissioners judge that the construction of the works contemplated by the Lackawanna Company will cause an increase of the currents of the flood waters of the river in that locality, to such an extent as to render the said water slope of the Erie Road liable to erosion by the water.

According to the ruling of the court the area of cross section, available for the passage of the flood waters of the river, will be sensibly larger than it was assumed in the foregoing calculations.

The river bridge will be actually extended by the bridge-openings west of it, for a distance of 405 feet; and since the materials under the bridge spans are to be excavated to the level of low water, a flood area of several thousand square feet will be added to the estimated amount.

Under these circumstances the increased head of water that will be produced above the bridges will, of course, be less than that computed by either one of the formulas applied.

PRACTICAL REMARKS ON THE SEASONING OF WOOD.

From "The Builder."

There have been promulgated from time to time so many different theories concerning the best way of seasoning wood, that, whilst taking the subject once more in hand, we feel that we are not only approaching debatable ground, but that we are stepping on to that which has been already well-nigh exhausted by writers.

Let us commence this paper by remarking that wood is an elastic material; that it expands under the influence of moisture; and that it contracts again when by the process of drying, known as "seasoning," the moisture has been evaporated from it. A thin coating of paint or other material, when applied to seasoned wood, may be the means of keeping out moisture, and, of course, if it be kept out, the wood will not be in any way affected by it; but if the moisture be permitted to approach dried wood, the sponge-like character of the material will absorb it, and it will expand in proportion to the amount of moisture that has been absorbed.

We have remarked that a coating of paint or other similar material will, when applied to wood, exclude moisture, and we may further remark that by the action of the evaporation of the natural juices of wood, it would appear that a sort of fine skin is given to the wood, which skin is sufficient, frequently of itself, to exclude moisture. We will furnish an example of this fact by detailing a case which came under our own observation. The flooring boards of an old floor in a dwelling house were taken up for the purpose of being replaned. They had been laid down considerably over twenty years. Before being taken up the joints were seen to be quite close fitting. After having been planed over the boards were relaid, and with the result that in about two months all the joints had considerably opened, and it was found to be necessary to again take up the boards and relay them, so as to secure close-fitting joints. It was the fact that by the removal of the old skin evaporation had recommenced, so the wood had undergone a second process of shrinking.

Wood requires time in which to season, very much in proportion to the density of its fiber. But this rule is not without an exception, for pitch pine, which is not at all a densely fibered wood, requires a long time in which to season, even when the process is conducted under favorable conditions.

This occurs probably in consequence of the resinous character of pitch pine, the resin clogging the pores of the wood, and thus stopping up the channels through which the moisture would otherwise exude. There are some woods,—and mahogany, ebony, and some other of the tropical woods are of the number—that even in their living state contain very little moisture.

Plants that are of slow growth contain less moisture when in a living state than do those whose growths are rapid. A mahogany tree requires 500 years in which to mature, and, as a consequence, its texture is exceedingly dense. Being dense in texture, it requires a long time to properly season, and during that lengthened period it shrinks very little. Mahogany should not be kept longer than necessary in the log, because insomuch as the outside portion of a log contains the greatest amount of moisture, and it being the exposed part, it will, as the wood dries, shrink more than the inner wood, and so, to allow for the outside shrinking, outside shakes will and must occur.

The same remark applies with equal force to all log timber, but we name the circumstance in connection with mahogany particularly for the reason that it is a general practice for some to keep their mahogany logs in an unsawn state, under the misapprehension that the logs do not deteriorate. When it is required to keep the logs in comparative bulk, it will be found to be a convenient method to have one cut put down the centre of them, which, as a rule, will be sufficient to obviate any tendency to outside shake that may arise in consequence of their shrinking on the outside. When cut mahogany boards should always be laid aside to season in the same order as they have left the saw. Strips of accurately-sawn wood should be placed at intervals of a not greater distance than 12 inches from each other, and we are inclined to advise that the strips of wood be placed even closer together than that.

It is advisable that some woods should be seasoned quickly, and others should dry slowly. Mahogany must be seasoned slowly. To season it thoroughly and well, periods should be allowed in something like conformity with the following table. Care should also be taken that the strips of wood which separate each board should have their positions changed at least once in each year, and the whole of the boards should have their sides reversed once in each year, so that the sides of the boards which were below should, by being reversed, be placed upwards, and *vice versa.* The remarks made concerning the seasoning of mahogany boards may be taken to apply also to wainscot oak boards.

TABLE APPORTIONING THE TIME TO BE ALLOWED FOR SEASONING MAHOGANY AND WAINSCOT OAK BOARDS UNDER FAVORABLE CONDITIONS:

Thickness of Boards.	Time to be allowed for seasoning in the open.
3/8 inch	12 months.
1/2 "	12 "
5/8 "	16 "
7/8 "	20 "
1 "	24 "
1¼ "	30 "
1¾ "	33 "
2 "	36 "
3 "	46 "
4 "	56 "

It is, perhaps, superfluous to add that some kind of improvised roof must be provided under which to shelter the seasoning board from the damaging effects of the sun, the rain, and dirt. It is the practice with some to preserve the ends of mahogany boards, when they are undergoing the process of seasoning, by nailing a strip of wood on the end of each board. Of this practice we do not altogether approve, for the reason that it retards, to some extent, evaporation. A roof which sufficiently overhangs the ends of the boards is a complete preventive, and is more advisable.

Newly-felled pine timber contains about 39 per cent. of moisture. The specific gravity of pine is (to water=1,000) 0.9121. It can be air-dried to 0.5502, and artificially dried to 0.4200. The specific gravity of fir is 0.8700. It can be air-dried to 0.4700, and artificially dried to 0.3800.

Insomuch as pine deals reach this country in a narow range of length, they can be placed in a position for drying which they would not well occupy if the range of lengths was longer. It is the practice with many joiners to "perch" their pine boards to season; but we are opposed to the practice of placing the boards in any position where they become dirty, and impregnated with smoke, dirt, and grit. We hold that the object to be attained in the seasoning of wood is to slowly evaporate the moisture which is in the wood, without permitting the wood to lose its sawn shape, and at the same time to keep it perfectly clean.

It is here worth while penning a few notes relative to the importance attached to keeping wood clean, because the matter is one which is, now-a-days, receiving considerable attention. It is only of late that steamships have been largely employed to bring over foreign sawn timber. Shortly after the introduction of steamships into the wood-carrying trade, timber importers had the advantages which these vessels afford over sailing ships made clearly manifest to them, by the preference which consumers of wood showed for the excellent condition in which the wood brought over in steamships reached them. The quick passages made by steamers afforded no time for any kind of fermentation of the sap to ensue, and there being no sea-washed deck-cargo to spoil the general appearance of a parcel, the preference for clean-looking stock began to direct the attention of consumers to the advantage of keeping seasoned wood also clean. There is no greater mistake made than to suppose, as some do, that the bulk of wood in a timber-merchant's yard necessarily improves with time. Timber importers learn to their cost that, instead of improving, it deteriorates very quickly indeed; and one of the questions which many timber importers have set themselves to consider is, whether it is not advisable for them to incur the cost of erecting large sheds under which they can store their better quality deals, and thus keep them clean.

Pine boards should be seasoned on very much the same plan as that which we have recommended for the seasoning of mahogany boards. We suggest only this alteration, that they should be placed where the wind can reach them, for they should be dried quickly. The reason for this is that pine is a wood which is prone to rapid decay, and therefore the quicker it can be placed in an absolutely dry position—such for instance, as being made up into internal joinery work—the better.

Redwood is a difficult timber to season properly. The lack of uniformity in the lengths of redwood deals renders the adoption of the same plan as that which we have suggested for the seasoning of pine boards inconvenient, because insomuch as the long boards would hang over the others the leverage would be certain to cause the boards to bend. Perhaps the best way is to place them on their edges in a frame although in this situation they would be likely to twist somewhat. The general practice is to "perch" them, but if they be at all "shelly," and "shelliness" is a fault usually attached to the finer kinds of redwood—such as Archangel and Onega redwood, the rain is apt to penetrate into the "shelly" parts of the boards, and should frost succeed the rain it splits and rives open the boards terribly. It would thus appear to be imperative that redwood should be seasoned under cover. Wind is a useful agent to assist in the drying of redwood.

Baltic whitewood, of all classes,

seasons quickly, and as the wood rapidly deteriorates under the action of the rain, the sun, and frost, the quicker it is dried the better.

Whitewood cannot be satisfactorily dried by artificial means, for it twists under the action of heat. Whitewood hardens very much by being exposed to the weather. The reason of this is that from its sponge-like texture the pores of the wood rapidly close when evaporation ensues.

We can recognize no advantage in incurring the expense of seasoning bearing woods. Of course, if the wood is positively wet, it must be dried of the superfluous moisture, but that may be considered to be sufficient. Flooring boards are best seasoned by being "perched" in an elevated position, where the wind can freely circulate through them, and cause them to rapidly dry. The ends of the boards should be well lifted out of the damp earth. Perches of different heights should be erected, so that the long boards can be dried upon a high perch, and thus they are prevented from bending sufficiently as to cause them to dry in a twisted form. For the sake of preserving the face sides of the boards clean, it is a good plan to "perch" the boards in pairs by placing two boards with their face sides together. They will dry perfectly well when so placed, and no little advantage is secured by having the boards turn out clean on the face side, for in a number of cases it will be found unnecessary to re-plane them when laid. We have commented, in the commencing portion of this paper, upon the danger of flooring boards undergoing a second shrinking process on the removal of the dried faces of the boards.

It may here be remarked, and the comment is well worthy of the attention of architects, that the shrinking of flooring boards when laid is oftener to be accounted for by the fact, that after the floor has been laid the boards have been replaned up so as to give a clean new-looking surface, than for the reason that the boards have been insufficiently dried.

The practice of drying the boards with their face sides together secures, as we have remarked, clean faces, and thus avoids the necessity of having the boards replaned after they have been laid, and as a consequence reduces their liability to shrink.

We have indulged in repetition on this point for the purpose of giving emphasis to our views, regarding them as being of some importance.

The system of stacking flooring boards to dry in triangular fashion is much to be condemned for several sufficient reasons. The first is that, when so piled, boards will hold no inconsiderable quantity of snow or rain water.

The second is that they do not dry in those places where the boards must necessarily touch each other in the crossing.

The third reason is that when the boards are in long lengths they have a natural tendency to "swag" in their centers, and so to dry in a twisted or crooked form.

It is to be borne in mind that, although wood the grain of which is of a twisted character has a natural tendency to dry crooked, yet that it can, by being judiciously weighted, be kept straight.

This fact, however, suggests to us that even straight-grained wood will dry in a crooked form, if, when left to season, it be allowed to assume a bent form, and that this being so it is imperative that the piling of wood into position for seasoning should be directed by care and intelligence.

THE results of a third year's observation of spirit levers at Secheron, for elucidation of periodic movements of the ground, to which we have several times referred, are given by M. Plantamour in the December issue of *Archive des Sciences*, and Col. von Orff also communicates results obtained at the Observatory of Bogenhausen—three to four kilometers from Munich. M. Plantamour shows that the oscillations, both in the east-west and north-south directions, present anomalies, or differences from year to year, which cannot be explained by mere variations of the temperature of the air. The earth's surface he supposes to be in a state of constant gentle undulation, the direction and amplitude of which varies in each locality according to the nature of the ground and the forces in action; and the effect may strengthen or neutralize that of the air temperature on the ground, or even produce a movement in an opposite direction. Col. von Orff's observations, *Nature* says, afford ground for supposing that the spirit-level variations are, partly at least, caused by variations of heat in the formation on which the observatory rests.

MODERN ORDNANCE.

By COLONEL MAITLAND.

From the "Journal of the Society of Arts."

A GREAT change has lately been taking place throughout Europe in the matter of armaments. Artillery knowledge has been advancing "by leaps and bounds;" and all the chief nations are vying with each other in the perfection of their *materiel* of war. As a readiness to fight is the best insurance for peace, it behoves us to see from time to time how we stand, and the present moment is a peculiarly suitable one for taking stock of our powers and capabilities. I propose, therefore, to give you this evening, a brief sketch of the principles of manufacture of modern guns, at home and abroad, concluding with a few words on their employment and power.

The introduction of rifled cannon into practical use about 20 years ago, caused a complete revolution in the art of gun making. Cast iron and bronze were found no longer suitable for the purpose. Cast iron was too brittle to sustain the pressure of the powder gas, when its duration was increased by the use of elongated projectiles; while the softness of bronze was ill adapted to retain the nicety of form required by accurate rifling.

From among a cloud of proposals, experiments and inventions, two great systems at length disentangled themselves. They were the English construction of built-up wrought-iron coils, and the Prussian construction of solid steel castings.

Wrought iron, as you are all aware, is nearly pure iron, containing but a trace of carbon. Steel, as used for guns, contains from 0.3 to 0.5 per cent. of carbon; the larger the quantity of carbon, the harder the steel. Since the early days of which I am now speaking, great improvement has taken place in the qualities of both materials, but more especially in that of steel. Still the same general characteristics were to be noted, and it may be broadly stated, that England chose confessedly the weaker material, as being more under control, cheaper, and safer to entrust with the lives of men; while Prussia selected the stronger but less manageable substance, in the hope of improving its uniformity, and rendering it thoroughly trustworthy. The difference in strength, when both are sound, is great. Roughly, gun steel is about twice as strong as wrought iron.

I must now say a few words on the nature of the strains to which a piece of ordnance is subjected when fired. Gunpowder is commonly termed an explosive, but this hardly represents its qualities accurately. With a true explosive, such as gun cotton, nitro-glycerine and its compounds, detonation and conversion of the whole into gas is practically instantaneous, whatever the size of the mass; while, with gun powder, only the exterior of the grain or lump burns and gives off gas, so that the larger the grain the slower the combustion. The products consist of liquids and gases. The gas, when cooled down to ordinary temperature, occupies about 280 times the volume of the powder. At the moment of combustion, it is enormously expanded by heat, and its volume is probably somewhat about 6,000 times that of the powder. I have here a few specimens of the powders used for different sizes of guns, rising from the fine grain of the mountain gun to the large prisms and cylinders fired in our heavy ordnance. You will readily perceive that, with the fine grained powders, the rapid combustion turned the whole charge into gas before the projectile could move far away from its seat, setting up a high pressure which acted violently on both gun and shot, so that a short, sharp strain, approximating to a blow, had to be guarded against.

With the large slow bursting powders now used, long heavy shells move quietly off under the impulse of a gradual evolution of gas, the presence of which continues to increase till the projectile has moved a foot or more; then ensues a contest between the increasing volume of the gas, tending to raise the pressure, and the growing space behind the advancing shot, tending to relieve it. As artillery science progresses, so does the duration of this contest extend farther along the bore of the gun towards the great desideratum—a low maximum pressure long sustained.

When quick burning powder was used for ordnance, the pressures were short and sharp; the metal in immediate proximity to the charge was called upon to undergo severe strains, which had scarcely time to reach the more distant portions of the gun at all; the exterior was not nearly so much strained as the interior. In order to obviate this defect, and to bring the exterior of the gun into play, the system of building up guns of successive tubes was introduced. These tubes were put one over the other in a state of tension produced by "shrinkage." This term is applied to the process of expanding a tube by the application of heat, and in that condition fitting it over a tube larger than the inner diameter of the outer tube when cold. When the outer tube cools it contracts on the inner tube and clutches it fast. The wrought-iron guns of England have all been put together in this manner.

Prussia at first relied on the superior strength of solid castings of steel to withstand the explosive strain, but at length found the necessity for reinforcing them with hoops of the same material, shrunk on the body of the piece.

The grand principle of shrinkage enables the gunmaker to bring into play the strength of the exterior of the gun, even with quick powders, and to a still greater extent as the duration of the strain increases with the progress of powder manufacture. Thus, taking our largest muzzle-loaders designed a few years ago, the thin steel lining tube, which forms an excellent surface, is compressed considerably by the wrought-iron breech coil holding it, which, in its turn, is compressed by the massive exterior coil. When the gun is fired, the strain is transmitted at once, or nearly at once, to the breech coil, and thence more slowly to the outer one. Now, as the duration of the pressure increases, owing to the use of larger charges of slower burning powder, it is evident that the more complete and effective will be the transmission of the strain to the exterior, and, consequently, the farther into the body of the gun, starting from the bore, and traveling outwards, does it become advantageous to employ the stronger material. Hence, in England, we had reason to congratulate ourselves on the certainty and cheapness of manufacture of wrought-iron coils, as long as moderate charges of comparatively quick burning powder were employed, and as long as adherence to a muzzle-loading system permitted the projectiles to move away at an early period of the combustion of the charge. Then, the pressures, though sharp, were of short duration, and were not thoroughly transmitted through the body of the gun, so that the solidity, mass, and compression of the surrounding coils proved usually sufficient to support the interior lining. Now that breech loading and slow powders have been introduced, these conditions have been changed. The strains, though less severe, and less tending to explosive rupture, last longer, and are more fully transmitted through the body of the gun. Sheer strength of material now tells more, and signs have not been wanting that coils of wrought iron afford insufficient support to the lining. It becomes, therefore, advantageous to thicken the inner tube, and to support it with a steel breech piece. Carrying this principle further, we shall be led to substitute the stronger for the weaker metal throughout the piece. This has been done by the Germans in the first instance, and recently by the French also. It is probable that we shall follow the same course. When I say "probable,' I intentionally guard myself against uttering a prediction. It is never safe to prophesy, unless you know, as the American humorist puts it. And in this case we do not know, for a very dangerous rival, once defeated, but now full of renewed vigor, has entered the lists against forged steel as a material for ordnance. This rival's name is *wire*. Tempered steel wires can be made of extraordinary strength. A piece of round section, only $\frac{1}{16}$ of an inch in diameter, will just sustain a heavy man.

If, now, a steel tube, suitable for the lining of a gun, be prepared by having wire wound round it very tightly, layer over layer, it will be compressed as the winding proceeds, and the tension of the wire will act as shrinkage. You will readily understand that a gun can be thus formed, having enormous strength to resist bursting. Unfortunately, the wires have no cohesion with one another, and the great difficulty with construction of this kind is to obtain what gun makers call end strength. It is of but little use, to make your walls strong enough, if the first round blows the breech out. In the early days of wire this was what happened, and Mr. Longridge, who invented the system, was compelled to abandon it.

Lately, methods have been devised in France, by M. Schultz; at Elswick, by Sir W. G. Armstrong & Co.; and at Woolwich by ourselves, for getting end strength with wire guns. They are all in the experimental stage; they may prove successful; but I prefer not to prophesy at present.

The diagrams on the wall show the general construction of the modern German, French and English heavy breech-loading guns. The Germans have a tube, a jacket, and hoops. The French, a thick tube or body and hoops. The English, a tube, a jacket, and an overcoat, as it may be called. In each system of construction, the whole of the wall of the gun comes into play to resist the tranverse bursting strain of the charge.

The longitudinal or end strength varies; thus, in the German guns, the tube and hoops do nothing—the jacket is considered sufficient. The French construction relies entirely on the thick body, while the English method aims at utilizing the whole section of the gun, both ways. Of course, if the others are strong enough, there is no particular advantage in this; and it is by no means improbable that eventually we shall find it cheaper, and equally good, to substitute hoops for the "overcoat."

I fear I have detained you a long time over construction, but it is both instructive and interesting to note that certain well-defined points of contact now exist between all the great systems. Thus, a surface of steel inside the bore is common to all, and the general use of steel is spreading fast. Shrinkage, again, is now everywhere employed, and such differences as still exist are matters rather of detail than of principle, as far as systems of construction are concerned.

We now come to a part of the question which has long been hotly debated in this country, and about which an immense quantity of matter had been both spoken and written on opposite sides—I mean muzzle loading and breech loading. The controversy has been a remarkable one, and, perhaps, the most remarkable part of it has been the circumstance that, while there is now little doubt that the advocates of breech loading were on the right side, their reasons were for the most part fallacious. Thus, they commonly stated that a gun loaded at the breech could be more rapidly fired than one loaded at the muzzle. Now, this was certainly not the case, at any rate with the comparatively short guns which were made on both systems a few year ago. The public were acquainted with breech-loaders only in the form of sporting guns and rifles, and argued from them. The muzzle-loading 38-ton guns were fired in a casemate at Shoeburyness repeatedly in less than twenty minutes for ten rounds, with careful aiming. No breech loader of corresponding size has, I think, ever beaten that rate. With field guns in the open, the No. 1 of the detachment can aim his muzzle loader while it is being loaded, while he must wait to do so till loading at the breech is completed. Again, it was freely stated that, with breech loaders greater protection was afforded to the gunners than with the muzzle loaders. This entirely depends on how the gums are mounted. If in siege works or *en barbette*, it is much easier to load a muzzle-loader under cover than a breech loader. But I need not traverse the old ground all over again. It is sufficient for me to say here, that the real cause which has rendered breech loading an absolute necessity is the improvement which has been made in the powder. You witnessed a few minutes ago the change which took place in the action of fired gunpowder when the grains were enlarged. You will readily understand that nearly the whole of a quick-burning charge was converted into gas before the shot had time to start; suppose for the moment that the combustion was really instantaneous. Then we have a bore, say 16 diameters long, with the cartridge occupying a length of, say, two diameters.

The pressure of the gas causes the shot to move. The greater the pressure, the greater the impulse given. As the shot advances, the pressure lessens; and it lessens in proportion to the distance the shot proceeds. Thus, when the shot has proceeded a distance equal to the length of the cartridge, the space occupied by the gas is doubled, and its original pressure is halved. As the shot travels another cartridge length, the space occupied by the gas is trebled, and its pressure will be but one-third of the original amount. When the shot arrives at the muzzle—that is, at eight times the length of the cartridge from the breech—the pressure will be but one-ninth of that originally set up. Remember, this is on the supposition that the powder has been entirely converted into gas before the shot begins to move.

Now, suppose the powder to be of a slow-burning kind, and assume that only one-third of it has been converted into gas before the shot starts, then the remaining two-thirds will be giving off additional gas, as the shot travels through the bore. Instead, therefore, of the pressure falling rapidly, as the shot approaches the muzzle, the increasing quantity of gas tends to make up for the increasing space holding it.

You will at once perceive that the slower the combustion of the powder, the less difference there will be in the pressure exerted by the gas at the breech and at the muzzle, and the greater will be the advantage, in point of velocity, of lengthening the bore, and so keeping the shot under the influence of the pressure. Hence, all recent improvements, has tended towards larger charges of slower burning powder and increased length of bore. And it is evident that the longer the bore of the gun, the greater is the convenience of putting the charge in behind, instead of having to ram it home from the front. I may here remark, that the increased length of gun necessary to produce the best effect is causing even those who have possessed breech loaders for many years to re-arm just as completely as we are now beginning to do. All the old short breech-loading guns are becoming obsolete. Another great advantage of breech loading is the facility afforded for enlarging the powder chamber of the gun, so that a comparatively short, thick cartridge may be employed, without any definite restriction due to the size of the bore.

There is yet one more point in which breech loading has recently been found, in the Royal Gun Factory, to possess a great advantage over muzzle loading as regards ballistic effect. With a shot loaded from the front, it is clear that it must be smaller all over than the bore, or it would not pass down to its seat. A shot thrust in from behind, on the contrary, may be furnished with a band or sheath of comparatively soft metal larger than the bore; the gas then acting on the base of the projectile, forces the band through the grooves, sealing the escape, entering the projectile, and to a great extent, mitigating the erosion of surface. This is, of course, universally known. It is also pretty generally known among artillerists that the effect of the resistance offered by the band or sheathing on the powder, is to cause more complete combustion of the charge before the shot moves, and therefore to raise the velocity and the pressure. But, I believe, it escaped notice till observed in May, 1880, in the Royal Gun Factory, that this circumstance affords a most steady and convenient mode of regulating the consumption of the charge, so as to obtain the best results with the powder employed.

Supposing the projectile to start, as in a muzzle loader, without offering any resistance beyond that due to inertia, it is necessary to employ a powder which shall burn quickly enough to give off most of its gas before the shot has proceeded far down the bore; otherwise, the velocity at the muzzle will be low. To control this comparatively quick-burning powder, a large air space is given to the cartridge, which, therefore, is placed in a chamber considerably too big for it. Supposing, on the other hand, the projectile to be furnished with a stout band, giving a high resistance to initial motion, a much slower powder can be used, since the combustion proceeds as if in a closed vessel, until sufficient pressure is developed to overcome the resistance of the band. This enables us to put a larger quantity of slower burning powder into the chamber, and in fact to use, instead of a space filled with air, a space filled with powder giving off gas, which comes into play as the projectile travels down the bore. Thus, while not exceeding the intended pressure at the breech, the pressure towards the muzzle is kept up, and the velocity very materially increased.

Following this principle to this conclusion, it will be found that the perfect charge for a gun will be one which exactly fills the chamber, and which is composed of a powder rather too slow to give the pressure for which the gun is designed; supposing the shot to move off freely. The powder should be so much too slow as to require for its full development the holding power of a band which is just strong enough to give rotation to the shot.

Having settled that the gun of the future is to be a breech loader, we have next to consider what system of closing the breech is to be adopted.

The German guns are provided with a round-backed wedge, which is pushed in from the side of the breech, and forced firmly home by a screw provided with handles; the face of the wedge is fitted with an easily removable flat plate, which abuts against a Broadwell ring, let into a recess in the end of the bore. On firing, the gas presses the ring firmly against the flat plate, and renders escape impossible as long as the surfaces remain uninjured. When they become worn, the ring and plate can be exchanged in a few minutes. Mr. Vavasseur, of Southwark, constructs his guns on a very similar plan. In the French guns, and our modern ones, the bore is continued to the rear extremity of the piece, the breech end forming an intermittent screw, that is, a screw having the threads intermittently left and slotted away. The breech block has a similarly cut screw on it, so that when the slots in the block correspond with the untouched threads in the gun, the block can be pushed straight in, and the threads made to engage by part of a revolution. In the French Marine the escape of gas is stopped very much as in Krupp's system; a Broadwell ring is let into a recess in the end of the bore, and a plate on the face of the breech block abuts against it.

In the French land service the escape is sealed in quite a different manner. A stalk passes through the breech block, its foot being secured on the exterior. The stalk has a mushroom-shaped head projecting into the bore. Round the neck of the stalk, just under the mushroom, is a collar of asbestos, secured in a canvas cover; when the gun is fired, the gas presses the mushroom against the asbestos collar, and squeezes it against the walls of the bore. It is found that this cuts off all escape.

We are at present using the Elswick method, which consists of a flat-backed cup, abutting against the slightly rounded face of the breech plug. The lips of the cup rest against a copper ring let in the walls of the bore. On firing, the gas presses back the cup against the rounded end of the breech block, and thus forces the lips hard against the copper ring.

It is difficult to compare the excellence of these various systems; so much depends on the care of the gunners, and the nicety of manufacture. The German and French marine methods permit the parts to be quickly exchanged when worn, but it is necessary to cut deeply into the walls of the gun, and to make the wedge, or breech screw, considerably larger than the opening into the chamber.

The Elswick plan is decidedly better in this last respect, but it requires several hours to extract and renew the copper ring where worn.

The French land service (*De Bange*) arrangement requires no cutting into the gun, and no enlargement of the breech screw beyond the size of the chamber, while it is renewable in a few minutes, merely requiring a fresh asbestos pad when worn. As regards durability, there is probably no great difference. I have been informed that with a light gun as many as 3,000 rounds have been fired with one asbestos pad. But usually it may be considered that a renewal will be required of the wearing surfaces of any breech loader after a number of rounds, varying from six or seven hundred, with a field gun, to a hundred or a hundred and fifty with a very heavy gun. Full information is wanting on this point.

Having now decided on the material of which the gun is to be composed, and the manner in which it is to be composed, and the manner in which it is to be constructed, and having, moreover, settled the knotty point of how it is to be loaded, we come to the general principles on which a gun is designed. It must not be overlooked that a gun is a machine which has to perform a certain quantity of work of a certain definite kind, and, like all other machines, must be formed specially for its purpose. The motive power is gunpowder, and the article to be produced is perhaps a hole in an armor plate, perhaps a breach in a concealed escarp, or perhaps destructive effect on troops. These articles are quite distinct, and though all guns are capable of producing them all to some extent, no gun is capable of producing more than one in the highest state of excellence.

Thus, for armor-piercing, a long pointed bolt, nearly solid, is required. It must strike with great velocity, and must therefore be propelled by a very large charge of powder. Hence an armor-piercing gun should have a large chamber and a comparatively small bore of great length.

For breaching fortifications, on the other hand, curved fire is necessary; the escarps of modern fortresses are usually covered from view by screens of earth or masonry in front, so that the projectiles must pass over the crest of the screen, and drop sufficiently to strike the wall about half-way down, that is to say, at an angle of 15° to 20°. To destroy the wall, shell containing large bursting charges of powder are found to be particularly well adapted. Now it is clear that, for a shell to drop at an angle of 15° or 20° at the end of a moderate range, the velocity at starting must be low. Hence, for pieces intended for breaching no enlarged powder chamber is wanted; the effect on the wall is due to the shell, which must be made of a shape to hold the most powder for a given weight; and, therefore, rather short and thick. This gives us a large bore, which need not be long, as little velocity is required.

For producing destructive effect among troops, a third kind of projectile is employed. It is called shrapnel, and it consists of a thin shell, holding a little powder and a large quantity of bullets. The powder is ignited by a fuse, which is set to act during flight, or on graze, when the shell is nearing the object. The explosion bursts the shell open, and liberates the bullets, which fly forward, actuated by the velocity of the shell at the moment of bursting. Hence, to render the bullets effective, a considerable remaining velocity is requisite. The gun must therefore take a large powder charge, while, as the shell has to hold as many bullets as possible, the bore must be large enough to take a short projectile of the given weight. Thus the proportions of the shrapnel gun will be intermediate between those of the armor-piercing gun and the shell gun.

There are certain axioms known from experience, which should be mentioned here. First, the length of the powder chamber should not be more than about $3\frac{1}{2}$ or 4 times its diameter, if it can possibly be avoided, because, with longer charges, the inflamed powder gas is apt to acquire rapid motion, and to set up violent local pressures. Next, the strength of a heavy gun, as reckoned on the principle of all the metal being sound and well in bearing, should not be less than about four times the strain expected.

Again, though there are several opinions as to the best weight of shot for armor piercing, in proportion to diameter, yet amongst the most advanced gun makers, there is a growing tendency towards increased weight. The value of $\frac{w}{d_3}$, that is, the weight in pounds divided by the cube of the diameter in inches, as this question is termed, is in the hands of the Ordnance Committee, and it is to be confidently hoped that efforts will shortly be made to arrive at a solution. In the mean time, from about .45 to .5 appears to be a fairly satisfactory value, and is adopted for the present.

Lastly, it may be broadly stated, that with suitable powders, a charge of one-third the weight of the shot demands, for most profitable use, a length of bore equal to about 26 calibers; a charge equal to half the weight of the shot should be accommodated with a bore of about 30 calibers; while a charge of two-thirds the weight of the shot will be best suited by a bore 35 calibers long. Of course, in each case, greater length of bore will give increased velocity, but it will be gained at the expense of additional weight, which can be better utilized elsewhere in the gun.

The amount of work performed by gunpowder, when exploded in a gun, is a subject which has engaged a vast quantity of attention, and some highly ingenious methods of calculating it have been put forward. Owing, however, to the impossibility of ascertaining how fast the combustion of large grains and prisms proceeds, a very considerable amount of experience is required to enable the gun maker to apply the necessary corrections to these calculations; but, on the whole, it may be said that, with a given charge and weight of shot, the muzzle velocity may now be predicted with some accuracy.

You now have the chief data on which the designer bases his proposals, and lays down the dimensions of the gun to suit such conditions as it may be required to fulfill. In actual practice, the conditions are always complicated, either by necessities of mounting in particular places, such as turrets and casemates; or by the advantages attending the interchangeability of stores, or other circumstances; and it requires great watchfulness to keep abreast of the ever growing improvements of the day.

I will now conclude with a few words on the power of the heavy guns, when employed in various ways. The first consideration is accuracy of fire. No matter how deadly the projectile may be, it is useless if it does but waste itself on air. Accuraccy is of two kinds—true direction and precision of range. All modern guns are capable of being made to shoot straight; but their precision of range depends partly on the successful designing of the gun and ammunition, so as to give uniform velocities, and partly on the flatness of the trajectory. The greater the velocity, the lower the trajectory, and the greater the chance of striking the target. Supposing a heavy gun to be mounted and in the fortresses round our coasts, and aimed with due care, the distance of the object being approximately known, we may fairly expect to strike a target of the size of an ordinary door about every other shot, at a range of a mile and a half. Here we have carriages mounted on accurately-leveled platforms; we have men working electric position finders, and the gunners live on the spot, aud know the look of the sea and land round about.

Now, consider the case of guns mounted in ships. You at once perceive the difficulties of the shooter. Even supposing the ship to be one of our magnificent ironclads, solid, steady, yielding little to the motion of the water, yet she is under steam, the aim of her guns is altered every moment, some oscillation is unavoidable, and she can only estimate the range of her adversary. Great skill is required, and not only required, I am glad to say, but ready to hand, on the part of the seamen gunners; and low trajectory guns must be provided to aid their skill.

If we go to unarmored ships of great tonnage and speed, we shall find these difficulties intensified; and if we pass on to the little gunboats, advocated in some quarters for attacking iron-clads in a swarm, we shall find that unsteadiness of platform in a sea-way renders them a helpless and harmless mark for the comparatively accurate practice of their solitary but stately foe.

The destructive power of guns is little known to the general public, and many wild statements are sometimes put forward. Guns and plates have fought their battle with varying success for many years. One day the plate resists, another day the gun drives its bolt through. But it is frequently overlooked that the victory of a plate is a complete victory. If the shot does not get through it does practically nothing. On the other hand, the victory of the gun is but a partial triumph; it is confined to a small arc. I mean, that, when the plate is struck at an angle exceeding 30° or so, the shot glances harmlessly off; while, even when perforation is obtained, it is at the expense of the more deadly qualities of the projectile, which must be a nearly solid bolt, unable to carry in with its heavy bursting charges of powder, or destructive masses of balls.

About six years ago, an experiment carried out at Shoeburyness taught a lesson which seems to be in danger of being forgotten. We hear sometimes that unarmored vessels are a match for ironclads and forts; and I will conclude this paper with a short extract from the official account of the results of firing shrapnel shell at an unprotected ship's side. I shall say nothing of boilers and magazines, but shall state simply the damage to guns and gunners.

A target was built representing the side of a certain class of unarmored ships of war; behind this target, as on a deck, were placed some unserviceable guns, mounted on old carriages, and surrounded by wooden dummies, to represent men working the guns. The attacking gun was a 12-ton 9-inch muzzle-loader, of the old despised type, and the projectiles were shrapnel shell. The charges were reduced to represent the striking force at a range of 500 yards. Two rounds did the following damage inside, besides tearing and ripping the ship's side in all directions.

1st Gun.—Seven men of detachment killed.

2d Gun.—Carriage destroyed; six men blown to pieces, all the remainder of the detachment severely hit.

3d Gun.—No damage to gun or carriage. Five men killed, one blown to bits, and one wounded in leg.

4th Gun.—Gun dismounted. The whole of the gun detachment blown to pieces.

That is the amount of destruction achieved in an unarmored ship by two rounds of shrapnel shell.

I beg to thank you sincerely for the kind attention you have given to me this evening.

DISCUSSION.

Gen. Sir John Adye, K.C.B. (Surveyor-General of Ordnance), said he should like to refer for a few moments, retrospectively, to the great development of artillery science, which commenced 25 years ago, and which, even now, hardly showed signs of having reached finality. England was amongst the first to use rifled ordnance, and at the outset the breech-loading system was adopted, the result being that we obtained guns with range and power far beyond anything known before. The system was consequently adopted with enthusiasm, and between 1858 and 1862, an expenditure of 2½ millions sterling was incurred in the manufacture of armaments for our fleet and fortresses. But although these guns had many excellent qualities, they soon developed serious defects; they were found to be delicate, liable to get out of order at critical moments, and accidents occurred to the men who served them. The result was, that a decided change of opinion took place; the officers and men, to some extent, lost confidence in their weapons, and were as anxious to get rid of them as they had been to obtain them. This led to the Government instituting careful inquiries; there were the Armstrong and Whitworth competition in 1863, various trials in 1864 and 1865, and committees appointed between 1865 and 1870, who all pronounced a unanimous opinion that a muzzle-loading system ought to be introduced. In consequence of this, for several years all guns up to 80 or 100 tons were made on that system. The Germans, on the other hand, adhered to the breech-loading system throughout, though in their early experience they met with many difficulties as we have done, and in the great Franco-German war, many of their field guns, though firing small charges, broke down, whilst the siege guns before Paris were weaker still. Indeed, Herr Krupp himself wrote to the *Times* in 1878, saying that after that war the German Government remodeled the whole of its field and siege breech-loading artillery. Both the War Department and the Admiralty in 1870, and again in 1875, expressed their confidence in our armaments, both as regarded power, range, and accuracy. In 1874 and 1875, in fact, England held a leading position in respect to artillery. At that time, no doubt, many people hoped we had approached finality; but their hopes were disappointed, for about that time another great stride was taken in artillery science, the full effects of which had not yet been realized. This great progress was due very much to the researches of the Explosive Committee, and partly to the experiments of other nations. That committee had been sitting from 1868 to the present day, and had gradually discovered that guns could be made of far greater power, range, and velocity than those manufactured seven or eight years ago; indeed, speaking roughly, he might say that the guns of to-day, whether muzzle or breech loading, were nearly double the power of those of the same weight made eight years ago. Some people were under the impression that a muzzle-loading gun was, in itself, weaker than a breech loader, but that was not so. Guns could be made on either system, practically identical in weight and power; rapidity of fire, he believed, was rather on the side of the muzzle loader. But it was found that these new types of guns required to be made of immense length and with large chambers, firing heavy charges, and in such cases there was an evident advantage in loading at the breech. At the same time it is hoped that the introduction of improved slow-burning powder will prevent the distressing accidents which sometimes occurred in early days. It was quite right, under such circumstances, that Government should institute careful experiments, with a view to the introduction of heavy breech loaders; but the progress of re-armament could not be very rapid. It was a work of time and expense, and he believed, also, that new ships would be required for the very large guns of the new type, so that re-armament must be gradual. With regard to the introduction of steel, he thought caution should be used; he could quote many accidents which had occurred to guns made entirely of steel, in particular two which had happened to Krupp's guns, one in Constantinople and another recently on board a German ship. So far as he knew, the wire gun, which had been under experiment by Sir William Armstrong, had given very remarkable results, and might possibly lead to a satisfactory solution of this matter. The Government had recently established an Ordnance Committee, for the purpose of considering the scientific questions involved in all these matters, consisting of distinguished officers of the artillery and Navy, and of two eminent civil engineers, one of whom he was pleased to see in the chair. This committee had a large accumulation of knowledge at their disposal, gathered both at home and abroad, and their was reason to hope that their reports would give confidence to the public. The Admiralty and the War Department were in complete accord on these matters, and the committee would be glad to receive assistance from civil engineers or others who had practical knowledge. There was a determination on the part of the Government that, in the future, as in the past, England should hold a leading position as to its armaments, and be prepared to guard the interests of the Empire in every part of the world.

Professor Abel said that though he had witnessed the development of rifled artillery from its earliest stages, and also the successive battles between breech and muzzle loaders, he should not have felt competent to speak on this subject, but for the fact that he was somewhat intimately acquainted with the propelling agent employed in guns, and also with the material used in their construction. In reference to what Colonel Maitland had said in his paper with regard to the preference shown by England for wrought iron, its employment was then a matter of necessity, and not of choice, because when rifled guns were first adopted, though we knew almost as much as we do now about the working of malleable iron in large masses, the knowledge concerning the production and treatment of large masses of steel was very limited. In fact, practically almost the only person who had successfully dealt with the production of cast steel in large masses was Krupp, of Essen, and even in his hands it was still a child, and the material he then produced was confessedly often unreliable. The English Government, advised by one of the most distinguished engineers of the country at that time, constructed rapidly and readily guns of wrought iron of considerable size, and which were, at that time, as superior in point of uniformity to cast steel guns as they were in point of strength to cast iron. Since then, we had learned much as to the properties of steel and how to deal with it; and, thanks to the development of the Bessemer and kindred processes, we could produce steel of high and uniform quality, and of the requisite softness and temper; and no one could now doubt that steel competed successfully with wrought iron as a material for ordnance. But even now, if it had not been for the improvements effected in the manufacture of gunpowder, steel would probably not be so applicable as it was for ordnance, since, even in its best form, it was, he believed, not so capable of resisting the sudden strains inflicted by violent powder as malleable iron; Colnel Maitland had told them that long after it was used abroad, it was found necessary to strengthen the breeches of steel guns by envelopes of wrought iron. The present improvements in gunpowder had originated in the researches to meet the requirements of the earlier rifled guns, carried out by the earliest Explosive Committee, of which he was a member; and the broad principle was laid down, which had up to the present been adhered to, that the proportions of the powder constitutents having been fixed upon as being calculated to give the maximum development of force for a given weight of material, it was advisable, if possible, to moderate its action, not by altering its composition, but by modifying its physical and mechanical characteristics. The improvements alluded to by Colonel Maitland had been entirely of that nature; great attention had been paid to means for regulating its density and hardness, and the size of the individual masses, and to other minor points necessary to secure uniformity, a result the attainment of which was by no means so easy as might be supposed. By these means they had succeeded, at first very gradually, but lately more rapidly, in moderating the rapidity of action of gunpowder, until it became comparatively manageable. But even these improvements introduced difficulties which it required all the skill of the manufacturer and the chemist to overcome. Amongst the difficulties incident to the use of large charges, was the erosion of the surface of the bore; and although this was partly overcome by means of bands or discs of soft metal, the erosion of guns was still a serious question which was taxing all their energies and skill to meet. Colonel Maitland had given some interesting views as to the effect of the retardation of the shot, and the gradual development of the force of the powder in large charges. The idea of retardation of the shot, referred to as a novelty, was mooted many years ago, and several plans were brought forward to effect it. With one or two exceptions, they were not very practical, and their object was scarcely the same as that aimed at by Colonel Maitland. But it did appear that the principle of retardation was applied in the earlier rifled service breech-loading guns, which fired lead-coated projectiles. The forcing of the soft metal coating into the rifled grooves had a retarding effect on the projection of the shot, and it was this very fact that led to the disovery of the necessity for moderating the rapidity of explosion of the powder then used.

Colonel Hope, V.C., wished to correct a slight misapprehension on the part of Colonel Maitland, with regard to Mr. Longridge having abandoned his steel-wire principle. From a letter received from him only yesterday, it appeared that he was still convinced that his principle was correct, and he was only afraid that Sir William Armstrong would fail because he was diverging somewhat from it. He had listened with great pleasure to the remarks of Sir John Adye. It was quite true, as he said, that at one time England was ahead of all other countries in heavy ordnance; but, nevertheless, he thought then, as he did still, that those immense guns were constructed on wholly erroneous principles; and that seemed to be now acknowledged, because those guns were already obsolete. With regard to the gunpowder, the composition was the same, and if there were any difference in the strength, the large sized powder was the weaker. You had only to stand behind one of these now obsolete guns when fired, and you saw grains of powder passing through the air outside the gun, showing that the whole of the powder was not converted into gas inside, and of course, any portion not so converted was absolutely wasted. The only gain obtained by increasing the size of the grains was that you humored the weakness of the gun, by making the combustion slower. If the gun were strong enough, the more violent the powder, giving the more complete conversion into gas, the better the result, as you got something of the effect of a blow as well as a push. If he mistook not, the powers of the Ordnance Committee were limited to certain matters which were referred to them; and therefore it was not of the nature of a scientific committee, able to undertake original research, and it did not at all follow that any system which might be ultimately approved would be the best, or the one which they would themselves have approved, had their powers been larger. He had heard with great pleasure the statement that the Government would welcome assistance from all comers, which was a complete change of affairs within one or two years. Theoretically, Government was always ready to receive assistance from anybody, but it was under conditions that few people would be willing to accede to. The consequence was that if any one were foolish enough to offer to assist the Government, they insisted on his surrendering all his secrets, and assisting in every possible manner, receiving only such reward as the Government Department itself should fix. He never could see why guns, ships, and kindred matters should be treated in a different way to every other question of a similar nature. If the War Office required an acre of land to increase an existing fortification, it could take it, but it had to pay a fair price, to be fixed by arbitration; and why should it arrogate to itself the right to sieze a man's invention, and use it, and pay him whatever crumb some one in authority chose to fling to him? He had just had the misfortune to lose, by death, one of his earliest friends, Sir William Palliser, a man who had made many inventions, some of which were taken up by the Government, and some were not. One of these was the converting of old smooth-bore cast iron guns into rifled ordnance. About 2500 of these guns were in constant use, and down to a very recent period, at any rate, not one of them had ever burst, or caused a serious accident; and he thought it was a great pity that this system had not been applied to larger guns, such as the one shown on the drawing. This principle was to line a cast-iron gun with a wrought-iron tube, and he thought it a pity that so cheap and easy a system had not been adopted instead of the more costly and cumbrous one which had already broken down. There was no doubt that foreign countries were ahead of us in the use of steel, with the single exception of this system of steel wire, which he did not profess to understand. Some specimens of guns he had seen on the Continent were altogether in advance of anything he had seen at home, and a gun, 18 feet long, was now being made for him on the Continent, of cast steel tempered in oil, which was altogether superior as regards metallurgy to anything he had seen in England.

Professor Abel said he had endeavored to explain that the composition of powder had been in no way changed, and the total force developed. With regard to burning particles being seen to come out of the gun, he believed the same thing occurred with the quickest and most violent powders used; but it was only a very small proportion of the charge. It was scarcely the correct view of the cause of modifications effected in gunpowder to say that they had been introduced to humor the weakness of structure of the guns; the real object and effect were to develop the full power of those guns. Artillerists now obtained velocities never dreamed of before, and with much less maximum pressure on the gun.

Major Charles Jones said it was quite true that there were a large number of the Palliser guns in the service, but they were all of a moderate size, the charge of the largest being 10 lbs. He believed the system had been recently applied in America to larger guns, but not very successfully, two having burst very recently. With regard to an observation of Colonel Maitland's, on the inaccuracy of fire from gunboats, he thought he had gone further than the gentleman he referred to intended. The vessels he advocated were cruisers, ranging from 2000 to 3000 tons burden, and they could scarcely be regarded as small boats, bobbing about on the surface of the ocean; in fact, the accuracy of their fire would be approximately as great as that of an ironclad. The argument was, that you would not have only one, but several cruisers fighting an ironclad, carrying an equal number of guns, moving with greater rapidity, choosing their own range, and concentrating their fire, whilst the armor-clad vessel would have to disperse her fire and aim at a much more rapidly moving object. There could be no question about the damage done to an unarmored vessel by heavy ordnance, but the damage done to an ironclad, although fewer shots got through, was not quite so small as the remarks made might lead one to suppose. When you got a Palliser shell, or even a Palliser shot, through, those projectiles themselves broke up, and not only so, but they carried with them pieces of the plate and backing, and bolts through in a shower, and the effect would be practically the same as the bursting of a shell inside an unarmored ship. As regarded the ribbon gun, two were made, to begin with, and the first one, made in 1879, had stood very large charges and showed no signs of failure; that was a six inch, but the one now under experiment was 10.263 inch. One reason why guns had grown in length was the advantage which had been found to arise from air spacing, firing the charge in a chamber not completely filled. That result was deduced from the experiments of Prof. Abel and Captain Noble, showing that pressure in a closed vessel was due to the density of the charge; as the density increased, so did the maximum pressure, and it naturally followed that by giving the charge in the gun less density, not filling the chamber, you were able to keep down the maximum pressure; but in order to get the full effect of the powder, it was necessary to lengthen the bore; and that, again, led to the adoption of enlarged chambers. That was begun some years ago, by Captain Noble, in order to give air-space, without unnecessarily encroaching on the bore.

The Chairman said that the more he considered the question of artillery, to which his attention had been directed for several years before he joined the Ordnance Committee, the more he was struck with the difficulties that surrounded the subject. A weapon was required which should not only be a source of danger to the enemy, but should also be so absolutely safe as to inspire the utmost confidence in those who used it. As a civil engineer, he was accustomed to deal with large pressures, as they were considered, of elastic vapors. Steam was now being used at a pressure of 1,000 lbs. to the square inch, which was thought very great, and great precautions were taken against accident. But this pressure sank into insignificance when compared to that in the chamber of a large gun, which was very commonly 17 tons to the inch, or 38,000 lbs., and sometimes went up to 25 and even to 30 tons. The problem was, to make a vessel which should bear this enormous pressure, without exceeding the elastic limit of the material. They all knew now that which was not so well known formerly, that if the bore of the gun were surrounded by a mere block of metal, with all the parts in a quiescent condition, without any initial strain, the pressure which came upon the interior of that block had to be resisted by the immediately neighboring metal, without that metal receiving any substantial aid from the metal further removed from the center; in that way the interior metal yielded, and was fissured, and when once this occurred the fissure increased until the whole gun was rendered unserviceable, or, perhaps, burst explosively. It was, therefore, found impossible in gun making to deal with metal in the ordinary condition in which an engineer was content to deal with it, and therefore recourse had been had to that which was known many years ago as a mode of obtaining the aid of the whole of the metal in the construction, when pressures such as obtained in the Bramah presses were employed; and it was on that principle that all modern guns were made. With respect to the wire or ribbon gun, while following the example set by the reader of the paper, and not attempting to prophesy until the event had happened, he could not help thinking that it would be well to investigate this subject thoroughly. Whether it would succeed or not he would not say, but the experiments which had been made were favorable. There was great simplicity of construction, and great certainty in some respects. You had not to deal with those difficulties which arose when metal was shrunk on at a high temperature, though he must admit that the great practice and skill in the gun factories, and the great knowledge of their superintendents, enabled this to be done with nearly absolute certainty. But when dealing with material in the cold state, as in the easily-manageable form of a ribbon, it was obvious that you could control the tension put upon it, you could wind it on as you wished, and if you did not like it, you could undo it. Again, you could not get any serious local latent defect, such as it was impossible always to avoid in a large mass of metal. If in the ribbon there were defects, they would only be local; and where you had twenty coils, one over another, surrounding a ten-inch gun, it was not likely that the defects would be cruel enough to occur in the same radial line in the whole twenty convolutions, or indeed that more than one of them would thus occur. Probably nothing but the most severe test would tell whether that construction which appeared so substantial, when first made, would be substantial after the concussions arising from repeated discharges; but he thought one might be very hopeful about it. He had been surprised to hear one observation from Professor Abel, which, in any view, he was sorry for. He should be very sorry to suppose that Professor Abel was wrong, but still more sorry if he were right. He referred to his observation that steel was less competent than wrought iron to resist a sudden action upon it. There was steel and steel, and if the observation had been made by some one who was not acquainted with the subject, and when thinking of steel had present to his mind a file, which would break in two if dropped on a stone floor, he should not have paid any attention to it; but, coming from a gentleman of Professor Abel's experience as a chemist and a metallurgist, he was surprised to hear it. He should certainly have said that steel was more able even than wrought iron to withstand percussive action. But he thought it was clear that, whether in the form of wire, or of hoops, or of forged pieces, owing to the changes in the powder and in other ways alluded to by Colonel Maitland, the large guns of the future would probably be made of steel, a metal which certainly would give a strength not to be obtained from wrought iron. Reverting again to the ribbon gun, he might remark that in a gun ordinarily weighing 25 tons, one might look in the ribbon mode of construction for a saving in weight of four to five tons, or if the weight were the same, to a proportional increase in strength. A question had been raised as to the longitudinal strength of ribbon guns, and reference had been made to three modes generally adopted for insuring it—the French, Sir William Armstrong's, and the mode adopted at Woolwich; probably any of these would suffice, but the French appeared to be cum brous, and if the drawings he had seen were accurate, he feared there might be a failure, not on account of the material, but because there were sudden changes of form which must lead to rupture. This, however, was a mere matter of construction, which could be easily altered, and might be only an error of the draughtsman who prepared the drawings he had seen.

Colonel Maitland, in reply, said he should not like any one to think he had omitted Mr. Fraser's name from any personal feeling. He worked with him every day, and he thought it would be almost like self-praise to mention his name particularly. With regard to Mr. Mallet, Tubal Cain, and others, he had not gone back so far. It was said that retardation for regulating the consumption of powder was old, but it was so new that until a few days ago it was not believed in. Like many other discoveries, people said at first there was nothing in it, and then they said they knew it all the time. In breech loaders, until very recently, they had always had large air spaces in order to mitigate the violent effects of the powder. But the air space was waste; if you filled it with powder it was more useful, and if you could hold the shot back so as to consume a slower powder at a steady pressure you could use a much larger charge. The other day he fired a 10.4-inch gun with 231 lbs. of powder and a large air space on the old principle, and the velocity obtained was about 1,950 feet. He then fired it with a very large charge of slow powder and strong band, and got 2,150 feet. With regard to the gunboats and cruisers, Major Jones seemed to know whom he alluded to, but the views he referred to were put forward by several others; and his special argument was against small gunboats, which were supposed to come out in swarms to attack an ironclad. He believed that half of them would be sunk. He heard an interesting lecture lately on the subject Major Jones alluded to, that of attacking an ironclad like the *Inflexible* by three large cruisers. An eminent engineer, he met coming out, said it was a very interesting subject, and he asked him which he would rather be in, the armored or the unarmored ships. His reply was, that in the present state of science he should prefer the ironclad ships, and he quite agreed with him. The principle of enlarging the chamber of guns, so as to hold a larger charge of powder, was thoroughly worked out in 1873 in the Royal Gun Factory; Major Jones appeared to think it was due to Captain Noble. (Major Jones disclaimed this, and explained that he referred only to the use made of enlarged chambers for air spacing.) Colonel Maitland said that in that case he had nothing to add, except to offer thanks for the kind attention given to him.

ON TORPEDO BOATS AND LIGHT YACHTS FOR HIGH SPEED STEAM NAVIGATION.

By JOHN ISAAC THORNYCROFT, M. Inst. C.E.

From Proceedings of the Institution of Civil Engineers.

II.

Mr. W. H. White, Assistant Constructor of the Navy, desired to allude to the bearing which the author's system of propulsion might have upon steam navigation at higher speeds than those generally obtained; but before referring to that subject he wished to draw attention to one or two points in the paper from a naval architect's point of view. The author had discussed the matter chiefly as an engineer. Mr. White would speak of it as a naval architect who might have to put engines of the torpedo-boat type into ships; and would endeavor to make clear what seemed to his mind the obvious limitations under which, in the present condition of things, the system could be extended. The torpedo boats, which he thoroughly admired as triumphs of engineering and constructive skill, were exceptional in almost every respect in which the naval architect could view them. There was extreme lightness of construction, extreme lightness of machinery, and (which the author had not dwelt upon with the force with which the naval architect would dwell upon it) an extremely small load carried. The author had stated that the weight of the hull in the torpedo boat, taken as a fraction of the displacement, compared exceedingly well with the weights of the hulls in large vessels. Of course, he was aware that while it was an interesting thing to express the weight of the hull as a fraction of the displacement, that comparison could only be applied fairly between vessels somewhat similar in structure and not very dissimilar in size. Speaking generally, he thought it might be said that in the torpedo boats the limit of lightness in one direction had been reached, viz., in regard to local strength and durability; unless some different and stronger material to build with could be found. He did not think the skins could be made thinner than $\frac{1}{16}$ inch, and that thickness did not admit of a very long wear. It appeared from Table II that the weight of the hulls in these boats was one-third of the displacement, and that ratio worked out to about the same in the "Devastation" and in the "Iris," the steel-built dispatch vessel. It should be borne in mind, however, that the torpedo boat was not nearly so elaborately fitted as a ship built for self-sustaining and sea-going service. The hull was a shell to carry powerful machinery and a light load of ornament; and the limit of the weight of the hull was fixed by considerations of local strength and durability. If torpedo boats were compared not with such large vessels as those mentioned in Table II, but with smaller boats, boats intended to bear the rough usage of actual service, such as large steamboats in the navy, the torpedo boat would not come out on the same line, but would be vastly lighter. The hull would probably weigh about half the displacement of a boat built in the ordinary way, whereas the author could build a satisfactory hull with one-third. He should be glad if the author would state in his reply if the percentage for weight of hull in the second-class boat was smaller than in the first class. With regard to the question of load, Mr. Yarrow had stated that, in a first-class boat, the addition of ten tons to the load would take 2½ knots off the speed. According to Table IV., the same boat (first-class No. 10) when tried with a small addition to the load, at once lost sensibly in speed. There had been cases in the navy in which boats when fitted up with a full torpedo armament had been tried, as compared with trials before they were so fitted, and it had always been found that there was a falling off in speed as the load was increased. He should not be doing injustice to the author's first-class boat in saying that, in doubling the load she had to carry, excluding the engines, but including coals, an addition would be made of from 40 to 50 per cent. to her displacement. That was an enormous addition to have to make for adding, say, 6 or 7 tons to the weight carried. In these designs, the shipbuilders were running on narrow and critical lines; and no one could study the matter as an outsider, without feeling that the author and Mr. Yarrow had been doing wonders in the limits within which they had to work. He had no desire to criticise, but merely wished to illustrate the fact that in torpedo boats there were extremely exceptional conditions. He agreed with Mr. Wright that for short passages, such as those of the channel service, it might be better to use the uneconomical engines (uneconomical as to fuel, but wonderfully economical as to weight) instead of the compound engines. In the fast vessels recently built by Mr. Samuda, M. Inst. C.E., simple engines had been used by preference for the Folkestone and Boulogne service, because of their relative lightness as compared with compound engines, accepting their more wasteful conditions as to fuel. But while this might be true for short passages, it did not hold for long voyages. For example, on the Transatlantic service, any one looking into the figures would see that, taking the coals and the engine together, there would really be a heavier combination to use those very light engines which burned practically twice as much coal, than there would be under existing conditions with compound engines. And as to the Australian service, the torpedo type of engines, if they could run all the way, could not be put into the ships now working on that service because of their high rate of coal consumption. The limits of employment of that type of engine under the present conditions of economy in fuel were very narrow, and it did not seem likely that the locomotive type of boiler, and the light, quick running machinery could be substituted for the present compound engines, until great changes had been made in their relative economy of fuel. He regarded the trials conducted by the author and Mr. Yarrow as model experiments in steam propulsion. Applying to those trials the law of "corresponding" speeds first indicated by Mr. Reech, and since worked out and applied to model experiments by the late Mr. Froude, imagination might extend from those tiny little vessels up to vessels of any size and any speed. Engineers might, perhaps, overpass the mark in some of these speculations as to the future; but, from the steam trials of torpedo boats, they could see with greater certainty what lay before them when they came to try and increase the speed of large ships. He had been endeavoring to see his way in this direction, and would give a brief sketch of the conclusions at which he had arrived. When a torpedo boat was under way, it appeared to be going almost in smooth water, except for a curious hump of water appearing here and there, along the length of the boat. He remembered a gentleman, when speaking on a paper by the late Mr. Froude, saying that the waves which were said to travel with the torpedo boats were imaginary, because the boats were practically in smooth water. That statement simply meant that the principal series of waves accompanying the torpedo boats were so large as compared with the boats that to a person on board they were unobservable: owing to their magnitude, they were beyond the reach of his observation. But when models of the same torpedo boats were tested in the manner proposed by Mr. Froude, all the beautiful wave phenomena which accompanied propulsion could be mapped out in detail, as had been done in a paper recently written by Mr. R. E. Froude. He had arrived at the interesting conclusion that, as a torpedo boat starting from a low speed was driven gradually to higher speeds, she passed through what might be called two phases. If, for example, she was driven at a speed under ten knots, she behaved as ordinary vessels would behave at ordinary speeds, say up to 14 or 15 knots. The resistance varied as the square of the speed; the vessel changed trim a little by the bow, and sank a little deeper in the water. That conclusion from the model had been verified by the author in actual trial, and the result would be found in the Reports of the British Association. As the speeds increased, the torpedo boat passed on, still like an ordinary ship, to a condition where the resistance varied at a greater rate than the square of the speed; in fact, he believed that in some cases it reached the $3\frac{1}{2}$ power of the speed. But as the speed was still further increased, the boat passed through a maximum rate of variation of the resistance in terms of the speed, and then it began to drop; so that the same boat which at 10 knots had a resistance varying as the square of the speed, and at 13 knots reached the 3½ power, at 18 knots had a resistance varying as the 1½ power of the speed; and beyond that the resistance diagram became a straight line, the power varying directly as the speed. The difficulty was how to get ordinary vessels to the speed where they behaved in that way. The author had attained this speed in his boats, and Mr. Yarrow also, but he must have been surprised the first time that result wa sobtained. Looking back at the trials with the "Miranda," no one could have been more surprised than the author at the result obtained at the higher speeds. When that curious change in the law of resistance took place, the boat which had been settling down a small amount, and going deeper into the water, behaved in that way no longer. She altered her trim, the bow seemed to come out of the water, and there was a bodily rise, so that if the whole situation could be frozen, there would be found less water displaced in weight than the weight of the boat itself. That change of trim most people had been inclined to believe was due, not to the wave slope, but to 'some variation in the fluid pressures along the bottom of the boat. It had now been proved by Mr. Yarrow from the boats themselves, and by Mr. Froude by means of his model experiments, that that was not entirely so. Mr. Yarrow had shown by actual measurement that the water surface alongside the boat, when the bow was apparently out of water, was nearly the same as in the still water: in other words, the boat was riding on the back slope of a wave which she had created by means of her machinery. When he was once in company with the author in a boat on the Thames, they seemed to be traveling in comparatively smooth water, but they suddenly met one of the saloon steamers, which thereupon danced about as if she had been a big cork, simply by the waves which the torpedo boat was causing, and which they had scarcely noticed until they had that means of observation. As to the speed at which similar phenomena might be expected to occur in large-sized ships, when the power would vary as the speed, a few remarks might be added. A comparison of form had been made in the paper between H.M.S. "Iris" and the first-class torpedo boats, and he would carry the comparison a little further. What would be the speed in a vessel of the size of the "Iris," —a torpedo boat enlarged—at which that condition of economical propulsion could be reached? He need not go into details, but the speed would be from 35 to 40 knots an hour in a vessel of 3,700 tons. At that rate the power would increase directly as the speed. The difficulty was how to attain that point. The ship would then be experiencing a resistance about $\frac{1}{20}$ of her displacement, and she would require, by the analogy of the torpedo boats, an engine power, to put it modestly, of 45,000 indicated HP. to drive 3,700 tons through the water at the speed which was economical when looked at in a certain way. He believed that a company had been formed to cross the Atlantic at a uniform speed of 20 knots. He had no wish to criticise the prospectus of that company; but, as a matter of fact, 20 knots in a ship of the size of the first-class ocean steamers would correspond to very low speeds in torpedo boats—to speeds in which they behaved just like ordinary vessels. Taking an Atlantic steamer of 10,000 tons displacement, he found that to get an economical propulsion such as was obtained at 18 knots in the torpedo boats, a speed of from 45 to 50 knots would be required. He had not thought it necessary in this case to work out the HP. He was not an engineer, and he would leave the author to say how 40,000 HP. could be usefully employed on a vessel of limited draught, what sort of propellers would be required, how the machinery was to be stowed in the ship, and how the power of traversing great distances at sea could be obtained under the assumed conditions. He did not think it could be done by simply pushing the locomotive system, which was so admirably carried out in the torpedo boats, to the larger scale that would be required. As far as he could see, if the existing "Iris" could have 45,000 HP. put into her hold, in the form of machinery resembling that used in torpedo boats, and equally light in proportion to the power developed, her coal supply would be reduced to 550 or 600 tons (instead of

750 tons as at present), and her rate of coal consumption would be so increased that, at full speed, she would only be able to run for about six or seven hours before her coal was exhausted. At all lower speeds, such as commonly occurred in practice, her coal consumption would also be very much increased by the adoption of the torpedo-boat type of machinery. He had the greatest admiration and respect for the work done by the author and by Mr. Yarrow; but, looking at the matter all round, he could not help thinking they were still left somewhat in the dark as to how similar operations could be carried out on a large scale.

Mr. Nathaniel Barnaby, C.B., Director of Naval Construction, could confirm the statement, as he feared all gray-bearded naval architects would have to do with some sorrow, that ten years ago they would have said that was impossible which the author had effected, and as he had achieved the impossible it might be well hoped that the impossible might be achieved again, if not by himself, by some one else. Mr. White had fairly stated the difficulties lying in the way of any attempts to get high speeds out of ordinary ships. He was speaking before gentlemen who were familiar with all the forces of nature used in the service of man, and he therefore spoke in the expectation that there might be some present who would set before themselves the problem how to get the enormous but necessary powers of which they had heard into ships of moderate size. He might mention as some encouragement that there was certainly one gentleman, Mr. Ramus, a clergyman, who thought that he had found a way of doing it. He had had some experiments made by Mr. Froude. His view was that it was possible to get high speeds with ships of a certain form which he proposed. He did not use the screw at all, but a rocket force to propel the ship. He was much disappointed when Mr. Froude's experiments led him to say that the result could not be accomplished in the manner proposed.

Referring to torpedo boats of high speed, another type, that of "Herreshoff," had been spoken of as a failure, but that was not a correct term to apply to it. It was a very clever boat, not an imitation of the author's, or of Mr. Yarrow's proposal, but a genuine American production. At least one boat builder in England had taken advantage of it, and produced an excellent arrangement by which he got a high speed going astern as well as going ahead. Mr. Yarrow had had some disappointment in regard to the speed going ahead, and he stated that he placed the screw under the keel of the boat as Mr. Herreshoff did. He had never asked the question, but it would be obviously necessary to have a different speed of engine, or a different pitch of screw, or both, in order to get as good a result when working in water which had a much higher speed with regard to the boat than the water which was at the stern. There might have been some difficulty in regard to the adjustment of the engine or the screw which had not yet been fathomed. At any rate, the results obtained by the Herreshoff boat were exceedingly good. The difficulty arose from the coiled tube boiler. In his view the boat was in no sense a failure, and he thought that in a year or two it would be acknowledged that England had gained a great deal by the experience which that boat had furnished.

Commander W. Dawson, R.N., remarked that when, a few years ago, he read a paragraph in a newspaper stating that the author had designed a vessel to go 20 miles an hour, he thought there must be some mistake in the figures, and when a little later it was asserted that the vessel went 20 knots an hour, he came to the conclusion that the statement must have been exaggerated. The next thing that struck him was the question, how many 20 miles would the vessel be able to do? It would be a lamentable thing for England if the base of operations for first-class torpedo boats were to be an English harbor. They should be able to go some little distance and make an attack, if necessary, on an enemy's coast. His attention had been a good deal devoted to the second-class boats. He was one of those who thought that, with all that the mechanical engineers had done for the Royal Navy, they had not altered the principles of naval warfare, and that a good deal might be learnt from the modes adopted by our forefathers. He might be permitted to mention one instance of the use of boats, occurring in the War of Independence among the South American Republics. At the port of Callao the Spaniards had a fifty-gun frigate called the "Esmeralda," manned by about four hundred or five hundred men, protected by powerful batteries, and outside were certain booms to protect her seawards. A valiant captain, Lord Cochrane, was determined to go in small boats alongside the ship as she lay at anchor, to climb her smooth side, get on board, and carry her out of port. He discovered that there was a narrow passage between the end of the boom and the surf on the beach, and that there was room for him to carry his small boats round. He went alongside at night, climbed up the side of the frigate, cut the cable, and carried her away, the batteries firing a shotted salute as he went. That, he thought, was as desperate as any work which torpedo boats would now be called upon to do. If Lord Cochrane had had any of the author's boats, what sort of conditions would he have liked to find in them? He would have liked the boat to be as safe as possible; and as he rounded the boom one of the first things that might strike him would be the danger of the fan blade striking the boom. It might not be possible to stop the engines before all three blades went; there would then be no means of moving the vessel, and the expedition would be at an end. If the screw were done away with that danger would be obviated. Then there was a danger of the heel below the keel touching the shore in passing round the boom, in which case the boat would be thrown by the surf broadside on the beach, and thus the expedition would be terminated. By getting rid of the rudder another element of danger would be avoided. An additional source of danger would be found on getting alongside the ship from the little bolts that often projected about the water line. When an attacking boat was once within gun power, the nearer it got to the large ship the safer; but if a thin boat made of steel $\frac{1}{16}$-inch thick ran against the bolts at the side of the ship, she would be apt to get a hole in her side, and the water would come in fast. Why not make the driving engines pump out the water, and steer the boat? All those problems had to be solved. It was possible to steer a vessel without a rudder, and if there were no screw propeller, the dead wood and stern post could be cut away, thus enabling the boat to turn round more quickly. Turning upon a pivot near the bow, the boat had to displace a wall of water, and of course, the less the height and length of that wall the better. All those objects could be accomplished by a change of the mode of propulsion. In the first place, it might be necessary to sacrifice some of the speed, but he had no doubt that Lord Cochrane in his expedition would have been glad to have the elements of safety to which he had referred at the cost of 3 or 4 knots in speed. There was one other danger to which torpedo vessels were exposed. Some eminent officers connected with the Royal Navy, to whose opinion he attached considerable value, had confounded the results obtained by gunnery experiments in peace, with what resulted in war. Certain experiments have been made with machine guns at Portsmouth and Shoeburyness for the purpose of determining which gun was the best, not for the purpose of showing what war was like. Those little vessels could not exist under a fire of heavy guns, machine guns, or even of ordinary lead bullets, if war was anything like what was shown by peaceful experiments. What war was really like might be seen from an example taken from the American contest. The "Albemarle" ironclad vessel lay alongside a wharf protected by her own guns, by guns on the wharf, and by troops on shore, and she had to be attacked and destroyed. A steam vessel—not one of high speed, like the author's—provided with a clumsy kind of torpedo, went in the night alongside her and blew her up. Unfortunately, amongst the hundreds of shot fired, one touched the boat and sent it to the bottom. The dangers to be anticipated from gunnery fire, by those little boats, was very small, and not at all like what happened in peaceful experiments. In actual warfare, it took a gun's weight in shot to kill a man; so that if a gun weighed 3 tons it would take 3 tons of shot to kill one man, and if the gun was 12 tons in weight, it took at least 12 tons weight of iron shot to kill him; thus showing that, from one point of view, the act of shooting had gone backward in the interval between the actions of the "Shannon" and "Chesapeake" in 1812, and that of the "Shah" and "Huascar," in 1878. The old rule as to lead bullets was the man's weight in bullets to kill him, and probably with breech loaders and rifles, still more lead was required. The machine guns had not been tried in naval warfare, but no doubt their hitting powers would be found equally uncertain under fire, and the author need not despair as to the utility of his beautiful boats under fire, because of the apparent accuracy of machine-gun fire as exemplified in such peaceful experiments.

Mr. T. R. Crampton desired to call attention to an important point which had not been referred to. Engineers were apt, in discussions on engines and boilers, to couple everything together and call it an engine. He confessed he was at a loss to know how to form an opinion as to the value of an engine and boiler when he was told that an engine was produced which only consumed 1½ lb. or 2 lbs. of fuel per indicated HP. That statement absolutely meant nothing, and gave no information. The author stated that his engine consumed 3½ lbs. per indicated HP. Mr. Crampton knew something of it, and therefore it conveyed some idea to his mind; but when Mr. Marshall said that the consumption would be 1¾ lb. he had no notion what that meant. How much water per HP. was used? If he were told that, then he could form an opinion whether it was the engine or the boiler doing its duty. There were plenty of bad boilers while the engines were extremely good, the total result being bad, yet the poor engines were condemned. It would be well to have the two elements separated. The author, in the straightforward way in which he did everything, had pointed out what he had done with regard to his boiler. From a visit which Mr. Crampton had paid to Messrs. Thornycroft's establishment in its early days, he was satisfied that those results could not be produced unless the fire went up the chimney. He soon saw that the fire did go up the chimney, and that the boiler was evaporating 1 cubic foot of water with three square feet of surface per hour, and that meant reducing the weight of the boiler something like two-thirds. To get the maximum out of the boiler, three or four times the surface was required. The author said, "I cannot afford to do that, and therefore I will sacrifice fuel in order to get lightness." "I know," he said, "that the jackets are good, but in my particular case, with high speeds, I will sacrifice the advantage in order that I may get a lighter machine; my great principle is to get lightness as far as I possibly can, and economy as a secondary consideration." That kind of machinery would not therefore be expected to be put into large vessels, nor would the author himself advise it. He had, however, done a very great deal, and, indeed, had accomplished that which had been said was impossible. He remembered that when the speed of 16 miles an hour was attained he discussed the question with a member of the Institution, and they came to the conclusion that it was almost impossible with ordinary preparation. When the speed was given, he said that there must be 60 HP. to do the exhaustion, and it turned out that there was 63 HP. or 64 HP. How was that done? By letting the fire go up the chimney. No one whom he had ever met had had so great an appreciation of the reduction of the weight to a minimum as the author. In the engine exhibited the weights of all the parts were reduced to a minimum. Even when so reduced, he took care to keep up the rubbing or wearing surfaces to a maximum. As to the question of how far the principle could be carried out in a large ship, it would be impossible to employ the system for the Channel service. There it was absolutely necessary to have a machine that would last, and that would give no trouble. As to jacketing, he thought it might be used with a saving of 30 per cent. of fuel, and a saving of 30 per cent. in the boilers, and that the saving of weight of the boilers would be such as to compensate for the extra weight of the jacketed engines.

Mr. William John wished to express his admiration of the work which Mr. Thornycroft and Mr. Yarrow had done. They had set all naval architects thinking, and the question had naturally passed through their minds, if it was possible to get a speed of 20 knots in a little boat, and the same speed in a big boat, why not in a ship of intermediate size? Mr. White had pointed out the difficulties in the way; Mr. John would not say they were insuperable, but the desired object could not be obtained with moderate-sized ships at the present time. With regard to the subject of vibration, he remembered some years ago being in one of Mr. Thornycroft's torpedo boats, and noticing that the effect of vibration at half speed was much greater than at full speed, and that there were very great differences in the vibration according to the variations in speed. That had been attributed in part to the revolutions of the screw synchronizing at some speeds with the natural vibration of the boat. He should like to know what the natural vibration of a boat was. He had taken observations on board ships several times as to the vibration, and it was a difficulty he had always experienced. In a tuning fork, or in a substance fixed at one end, there was a natural vibration; but in the case of a vessel floating free at both ends there was an entirely different time of vibration at the bow from that at the stern. He had observed the stern vibrating twice as rapidly as the bow. As to the question of stability, he had recently had to investigate the stability of some torpedo boats built by Mr. Yarrow, and he could bear out the statement of Mr. Thornycroft that the boats had a very large range of stability, and a great safety against capsizing. There was one other point to which he wished to refer. He did not think the facts would bear the generalization that had been put upon them in the paper. "To augment the stability, the width of the deck may be increased considerably beyond the width measured at the water line. The increase of bulk thus effected augments the righting force, when any considerable inclination of the vessel from the vertical is reached, without impairing the speed." That was often the case, but not necessarily at all large angles. It was so generally, however, with torpedo boats, yachts, and other small craft. But the width of the vessel above the water line might be increased and the range of the stability diminished. He thought that point was not sufficiently appreciated. By increasing the breadth of the deck the weights above water were naturally increased, the center of gravity was lifted, and there was a reduction of initial stability and range of stability in that way. But beyond that, even without any change in the position of the center of gravity, the effect might be produced of reducing the range. For instance, if a cylinder was loaded at all eccentrically, if the weight were put so that the center of gravity would come below the center, the cylinder had practically all the properties of a life boat; there was only one position of stable equilibrium and one position of unstable equilibrum, so that the curve of stability would practically have a range of 180°. If the center of gravity were lowered the range would be kept the same, and the curve would be increased. What occurred when the breadth above the water line was increased in such a case might be as follows: Supposing a broad deck to be put on to the vessel without adding to the weight, what was obtained was a vessel which, when turned bottom up, would practically have a broader water line than before, and would really have stability in the bottom up position, so that here was a body that was in stable equilibrium when it was floating the right way up, and also in stable equilibrium when it was floating bottom up, and there must be an intermediate position of instability. The range must therefore have been reduced from 180° by the change made. He only gave an indication of what might occur, but he thought it was a point worth considering when drawing general inferences as to alterations of stability from alterations of the form above the water line.

Mr. F. J. Bramwell, Vice-President, said the author had done him the honor to refer to certain experiments he had made nine years ago with one of his early boats, the "Miranda." That boat gave results which up to that time were entirely unknown, results which it had been stated by high authorities on naval architecture could not possibly be attained. In fact it was well known that one gentleman had said a boat under a given length could not be propelled beyond a certain rate by engine power at all, without a cost so excessive that it would be cheaper to carry it on men's shoulders. The author, by the construction of the "Miranda," showed that those statements were inaccurate, and that it was possible, by a judicious construction of the hull and a due proportionment of engine and boiler power, and by having regard to the weight of the structure, to attain the speeds which had previously been thought to be, with vessels of the size with which the author was then dealing, beyond the range of possibility. He exhibited a copy of one of the diagrams referred to in the Transactions of the Institution of Naval Architects, before which institution his paper in reference to the experiments on the "Miranda" had been read. Other diagrams accompanied that paper, but he thought the one now exhibited would suffice for the present meeting, as it contained the gist of the experiments. It would be observed that there was shown by the sloping line the gradual increasing speed of the screw, which was of 3 feet 4 inches pitch, and thus, at the six hundred revolutions, attained a rectilinear velocity of 2,000 feet in a minute. Experiments were made at two hundred, three hundred, four hundred, five hundred, five hundred and fifty-five, and six hundred revolutions, and the speeds attained were respectively 7 miles (not knots), nearly 10, nearly 12, 16¾, and 18⅝ at five hundred and fifty-five revolutions. The HP. developed was also shown to be from 4 HP. at two hundred revolutions up to 71 HP. at six hundred revolutions. It would be seen that the growth of the HP. at the increasing revolutions was such as to present a fair curve. With respect to the slip of the screw, this was only 7 per cent. at two hundred revolutions, but increased to 13 at three hundred, and got up to 21 at four hundred, then decreased to 14.7 at five hundred, and to 11.3 at five hundred and fifty-five. The author had mentioned that, having regard to the apparently anomalous result obtained by the falling off in the slip, and the apparent increment of speed of vessel compared with the speed of the screw as the pace got greater, the experiment was repeated, and the repetition showed the accuracy of the results previously recorded. The experiments were made with very great care, and he thought that they were in every way trustworthy. It was at first found somewhat difficult to obtain the indicator diagrams, but by a little management they were got with a great degree of certainty at six hundred revolutions per minute. The management consisted in using a very strong spring, so as to limit the vertical stroke of the indicator to get rid of the momentum of the piston and other parts of the indicator, and also in using a supplement to the rotating spring of the indicator cylinder, and in being content with a very short diagram, the intention being that the diagram should not exceed one inch in height and one in length. At six hundred revolutions it was not possible to see the indicator at work; it disappeared in a sort of "burr"; but the diagram was quite clear, and could be readily worked from, giving accurate indications of the power, as was proved by the repetition some weeks after the first diagrams were taken. Since that time, the author, having special regard to torpedo purposes, had improved his boats by making them condensing. The "Miranda" was not a condensing boat, and was, therefore, liable to the defect of exhibiting a stream of escaping steam—exhaust steam— which would render it visible to an enemy. The problem of making engines of the high speed of six hundred revolutions a minute, or even of the lower speeds obtaining in larger powered engines, condensing, was a somewhat difficult one if the air pumps were to be worked off the engines, which the author wisely preferred; but he had shown that by a judicious proportion of the valves and the stroke of the air pump to that of the engine, it was feasible to derive the motion of the air pump from the engine, and to procure all the benefits of condensing for the engines. They had since been made compound, and in that way the quantity of steam needed being diminished, the size of the boiler had not been increased in the same ratio as the power of the engines. He gathered that the author had, by bringing his paper before the Institution, proposed to do two things—one to tell the members frankly what he had done, the other to ask for comments and criticisms as to what might be further done in the way of improvement. He believed the author was not wedded to any particular system, and had no objection to take advice, but was glad to hear all that could be suggested. The author had called attention to the benefits that would attend reduction in weight. With respect to this question, Mr. Bramwell did not find in the paper the actual statement of the weight of the boiler and of the water in the boiler, but no doubt it must be a very large percentage of the total weight of the engines. He had, however, endeavored from the information afforded in the paper, to calculate the weight of the boiler and of the water in the first-class torpedo boat. Obviously where there was a boiler of the locomotive construction, the exterior of the boiler must be made of plates of sufficient strength to bear the pressure. A boiler four feet five inches in diameter, working at the pressure at which the author's engines worked, could not be dealt with lightly, and therefore a considerable weight was of necessity involved in the construction of that kind of boiler. Moreover, the whole of the plate surface which confined the water and the steam was inoperative as heating surface, and therefore the very surface which demanded the greatest amount of metal and added most to the weight of the boat, was surface which in no way tended to generate steam. The nature of the boiler also demanded that a considerable quantity of water should be accumulated in it, in order that the tubes and the top of the fire box might be covered. He was well aware of the value of a considerable quantity of water in a boiler, as being in itself the best reservoir of heat for the boiler, and he was also aware that if the amount of water in the boiler could be diminished it would be necessary proportionately to increase the watchfulness of those in charge of the engines, unless they resorted to boilers like the Herreshoff boiler, where there was no store of water, but a mere injection, nearly all of which was turned into steam. This was going back to the early type of injection boiler. He referred to the so-called Quicksilver engine, in which the boiler was provided with a double bottom, the space between the two plates at the bottom being filled with an amalgam of quicksilver which absorbed the heat from the fire at altimes, and gave it out again at each half reciprocation of the engine to the water which was projected upon the upper heated surface—an indented surface—and was at once turned into steam, and was immediately introduced into the cylinder. This construction of injection-boiler worked very well, he believed, for a year or two in a boat trading from London to Ramsgate. The engines were made by Penn; the invention of the amalgam to absorb the heat of the fire and to store it up until delivered to the wtaer as injected, was the invention of the late Mr. Howard, of the King and Queen Ironworks, Rotherhithe. But even if a boiler of the class he had mentioned—one of those which did not contain water, but which simply served as heaters of water—were not employed, the question then arose, if lightness were sought (and it was clear from the statements of the author and other speakers that in such boats lightness was of the essence of speed), should the use of the locomotive boiler be continued, or should some water-containing boiler, where all the surface was steam-generating, be resorted to? On this point he desired once more to refer to another boiler of which he had so often spoken, namely, Hancock's. As far as he could make out, a boiler of that construction would be about 2½ tons lighter, taking into account the boiler and the water, than the boiler (and water) would be if of the locomotive type employed in the first-class boat as described by the author. He would not weary the members by repeating the construction of the Hancock boiler, but he might mention that the whole of the surface was used in generating steam. It was true it involved a non-conducting envelope round the fire. One like that used by Mr. Perkins for his boilers would be admirably suited for the purpose, consisting of two thicknesses of iron with vegetable black between. An envelope of that character would admit of a high heat on one side, while the hand might be harmlessly put upon it on the other side. If a Hancock boiler thus cased were used he believed that 2 to 2½ tons would be saved in the weight of the boiler and the water in a first-class torpedo boat. The question also arose whether a further saving could not be made by venturing upon higher pressures than were used by the author at present. It appeared to him that if those higher pressures were employed, more effect would be obtained out of the steam. He did not wish to refer to the economy of fuel when the object was to launch a torpedo against an enemy, as in such cases it mattered ve.y little whether

1s. or £1 were paid for the fuel. In fact it was unnecessary to consider economy of fuel on such occasions. Yet, if it was practicable to have a more economical system of engine by the use of higher pressures, it would end in a smaller and therefore a lighter boiler. It would also lead to this, that the fuel carried would afford a greater number of hours' steaming than would be possible with a less economical engine. Upon those grounds, therefore, and not upon the ground of the desirability of saving a few shillings or a few pounds in the use of the boats for the purposes for which they were required, he thought it would be well if the author would devote his attention to the construction of a different form of boiler from the locomotive boiler, and to the adoption of a higher pressure of steam. In those two ways, he thought a reduction of weight, which appeared to be the great desideratum, might be looked for. He did not see how the engines themselves were to be reduced in weight except by an increase of piston-speed, which at present was very high; and although he was far from saying it might not be made higher, he should be inclined to seek economy in weight in the direction he had indicated, rather than seek it, in the outset at all events, in an increase of speed of the engine.

Mr. W. Schonheyder thought the statement in the paper that "a relatively high speed of engine may be taken as favorable for economy of steam, in consequence of the smaller area of cooling surface in the cylinders of high-speed engines than in those of low-speed engines exerting equal power," required some further explanation. In all steam engines there were two losses: the external loss due to radiation, and the internal loss due to the condensation from work done during expansion; and in order to decide if it was of advantage to work an engine at a high speed or a low speed, it was necessary to distinguish between engines that were jacketed and those that were not jacketed. In an unjacketed engine it was an advantage to work fast, inasmuch as the extent of cooling surface became small in proportion to the amount of steam passing through the engine in a given time; therefore the condensation was less, and the engine worked more economically. But in an engine that was steam-jacketed it might be, and often was, a great advantage to drive the engine slowly, because then the amount of jacket surface which was available in proportion to the amount of steam passing through the engine in a given time became positively larger, and prevented the large amount of condensation which took place in engines driven at a high rate of speed. It was for that reason that many engines, at a comparatively low pressure, 40 lbs. or 50 lbs. per square inch, had done exceedingly good duty at low speeds. It appeared to him that the question of jacketing was very little understood, but he thought that the whole thing was in a nutshell. An engine which was surrounded simply by an envelope of steam was called a jacketed engine, but very little account was taken of whether the engine exerted a large power or a small power. The jacket was wanted for the purpose of supplying the heat which was lost in the cylinder when the expansion took place, and whether the engine was working at ten or at one hundred revolutions a minute, the jacket ought to be made in proportion to the amount of heat which was to be imparted to the working steam. He believed it was the first time that attention had been directed to that particular point. As jackets were, as a rule, simply envelopes round the cylinder it was no wonder that people sometimes found that they were of very little use, and in the engine which the author had described he considered the jacketing, as usually carried out, to be quite useless. The author had found no advantage in the jackets, simply because they were so arranged that it was impossible to impart sufficient heat to the steam in the cylinder to make up the loss by condensation; but there was a positive advantage in jacketing when well carried out. He wished to quote some experiments by Messrs. Bryan Donkin & Co. upon an engine tested with jackets and without jackets at the same pressure. With jackets there was a development of 46.21 indicated HP.; without, 27.78 HP., the same pressure being used in both cases, and the vacuum being practically the same. The water evaporated per indicated HP. per hour was 22.51 lbs. with jackets, and 32.72 lbs. without jackets. The author had directed attention to experiments made in America with the steamer "Rush," in which the cylinders were steam jacketed, with 82 lbs. per square inch initial pressure. The most economical ratio of total expansion was 6.22. If the jacketing was insufficient, only a small amount of expansion could be carried out. With regard to the screw propellers, he did not say that the propeller shown by the author might not be a very efficient one for torpedo boats; but it imparted a large amount of rotary motion to the water. Attention had been called to that point by Mr. Yarrow, who referred to the stationary guide blades as having been employed for stopping that rotary motion. These guides were invented by Mr. Arthur Rigg, in 1863–4, who found a great advantage in using them, as they stopped the rotary motion of the water, and converted it into an after motion. But when they were employed it was necessary to make the screw and the guide plates of a proper shape.

Mr. George R. Dunell said any one who had seen the quickness with which Mr. Herreshoff's boat moved when the engines were started, the readiness with which the vessel stopped, and the command which the propeller seemed to have over the boat, would acknowledge that it must be placed in a very advantageous position. It was principally with a view to the manœuvering properties of the boat that the screw was put under the boat. It would be remembered that the vessel was steered in circles of very small radius, going either ahead or astern. The fore and aft trim, when going at a high speed, was also kept much better than was usual in torpedo boats, and that was largely due to the position of the propeller. Valuable as Mr. Yarrow's experiments were, he thought they could hardly be said to bear upon Mr. Herreshoff's boat. Mr. Yarrow had used a straight shaft, while the shaft of Mr. Herreshoff's boat was bent, or rather, sprung; so that the screw was kept nearly at right angles to the water line of the boat. That sprung shaft was the most surprising feature in the boat; but that it was a desirable arrangement required, in the opinion of many, further proof. It was the result of six or eight months' continuous experiments on the part of Mr. Herreshoff. Mr. Dunell was present at Portsmouth when the shaft was taken out of the torpedo boat for examination. After running for some time, it was confidently expected that it would be worn down to a considerable extent, but the tool marks were visible in the shaft after that long running. The boat obtained, on the official trial trip in the Thames, a speed of nearly ¾ knot higher than had been reached by any boat of the class on an Admiralty trial trip up to that time. He wished to be allowed to refer to a boat built by Mr. Herreshoff for the American government in 1876, and described in the Annual Official Report of the Secretary of the United States Navy. It was built of wood; length over all, 58 feet; beam, 6 feet 3 inches; depth, 3 feet 2 inches. There was one Herreshoff boiler, and a pair of ordinary non-condensing launch engines; the cylinders were 5 inches in diameter, with a stroke of 10 inches. On a trial trip, the boat ran 20.24 statute miles in 59 minutes and 43 seconds. On the down trip the steam pressure was reported steady at 140 lbs. per square inch; and on the return trip, the average pressure was only 100 lbs. A small pipe connecting the steam guage gave way, and it was plugged with a piece of pine without the boat being stopped, low-pressure steam being generated meanwhile. The "Miranda," the parent of all fast launches, was 50 feet long, and the beam on the water line was 5 feet 9½ inches. The vessel had a pair of engines 6 inches in diameter by 8 inches stroke. It was, however, to the comparative weight of the machinery in the two boats that he wished to call attention. According to a paper read by Mr. Bramwell before the Institution of Naval Architects in 1872, the weight of the "Miranda's" machinery, with the water in the boiler, was 4,500 lbs. The total weight of the machinery in the American boat, exclusive of the water in the boiler, was 3,132 lbs., and, allowing 268 lbs. for the water in the boiler, probably double the actual weight, the difference in the two weights was 1,000 lbs. in favor of the American boat. From what he had seen of the "Miranda's" engines, he should judge that they were at least as light as those in the American boat; and he thought there was little doubt that the difference in weight was due to the lightness of the Herreshoff boiler and the small quantity of water which it contained. The American boat was eight feet longer than the "Miranda," and 4½ inches wider; the speed was, as nearly as possible, 2 miles an hour faster than the "Miranda's." The trial trip took place in salt water, with non-condensing engines; the distance was 20 miles, and the boiler was fed with salt water the whole time. He did not wish to make a comparison of the speeds, but rather to draw attention to the difference in the weight of the engines. There was no record that diagrams were taken of American boats' engines, and he could not therefore bring the comparison to a very fine point; but he thought he had said enough to make out a *prima facie* case to show that something might be gained in speed by the use of the Herreshoff boiler. The American boat had been running since 1876, and, he believed, was running still, having used salt water the whole time. There was a method of detaching the scale by heating the coil. The coil would bear heating without damage, and, by the metal expanding, the scale was cracked and blown off. Still, as a rule, the use of salt water was not recommended, for it was difficult to get the people in charge to pay proper attention to keeping the coil free from scale. He was glad to say that Mr. Thornycroft was about to put Herreshoff boilers into two of his boats at the request of the Admiralty, so there would then be an opportunity of seeing what a boiler of that description would do in conjunction with the best machinery for that class of work. As to the consumption of coal, Mr. Donaldson had said, in a paper read before the United Service Institution, that he thought the Herreshoff boiler would be more wasteful as regards fuel than the ordinary boiler. Mr. Isherwood, in America, had completed some extensive experiments on coal consumption in the Herreshoff boiler, in which he had obtained 1 indicated H P. with 2 lbs. of coal per hour in a small yacht 100 feet long, with compound condensing engines having 9-inch and 16-inch cylinders with an 18-inch stroke. A report would shortly be published by the United States naval authorities on a series of experiments made on some vessels fitted with Herreshoff boilers, and extending over a period of three months, the boats running from 5 or 6 o'clock in the morning until 9 o'clock at night, twenty-four thousand indicator diagrams having been taken. It had been stated that the Herreshoff boiler was simply an old invention resuscitated after having been cast aside as worthless. There had been pipe boilers, coil boilers, and other water-tube boilers of various kinds; and, no doubt, to casual observers, they appeared much alike. The gentleman who remarked on the antiquity of the Herreshoff boiler, as an amateur experimentalist, was not perhaps required to be so searching in his inquiries as those who had more material interests at stake. There had been a great many inventions in high-pressure steam made by the very talented family to whom reference had been made; but the invention of the Herreshoff boiler was entirely due to Mr. Herreshoff.

Mr. J. F. Flannery felt it ought not to be forgotten that Mr. Yarrow was the first to attain a speed with his vessels of 22 knots an hour, although Mr. Thornycroft had been the first to attain a speed of 19 knots. At present it was difficult to distinguish between the labors and the results obtained by those two gentlemen; and in considering and placing on record the strides that had been made in modern machinery, introducing almost a new era, he thought that the names of Mr. Thornycroft and of Mr. Yarrow should be mentioned side by side, and he believed that no one would more cheerfully agree to that being done than the author himself. Mr. White had shown how the reduction of weight in machinery reacted upon the size of the vessel necessary to perform a given duty: how by reducing the weight of the machinery the necessary size of the boat was reduced, and how that again in a secondary degree reduced the size and weight of the machinery. He did not think it was possible from a naval architect's, or from a shipowner's, or from a marine engineer's point of view, to exaggerate the importance of lightness. It appeared from the paper that lightness had been obtained in torpedo boat machinery by two general means. The reduction in weight of the machinery was effected by increasing the piston speed, and the reduction in weight of the boiler by increasing the rate of evaporation per square foot of fire grate. The author did not indicate that in his opinion there was any loss of efficiency by increasing the piston speed, and Mr. Flannery would point out that the high speed which had been obtained, 880 feet per minute, might be possible with other than small engines. In the "Parisian," which was recently tried on the Clyde, the stroke of the engines was 5 feet, and the number of revolutions was allowed by Mr. Kirk, M. Inst. C.E., the designer and builder, to increase to as many as eighty-five per minute, thus giving the enormous and unprecedented speed of 850 feet per minute for an engine that indicated 6000 HP. It had thus been shown that under certain conditions it was possible to increase the speed of the piston enormously in large engines in comparison with those running at the present time. In regard to the increase in the rate of combustion, and to the reduction in the weight of the machinery by that means, where the author had a pressure of a blast corresponding to a height of 2 inches of water, the coal consumed per square foot of fire grate amounted to 49 lbs.; and where he had a pressure corresponding to 6 inches of water it amounted to 96 lbs. This tended to show that although the blast was increased considerably, a proportionate increase in the rate of combustion could not be expected. At the same time the economy was reduced by one-seventh. That disadvantage had been clearly pointed out by the author. Another disadvantage might also be inferred from one of the lines in the table. It would be observed that when the low pressure of the blast was applied to the boiler, the duration of the experiment was two hours; but that when the higher pressure of blast was applied, the duration of the experiment was one hour and twenty-seven minutes. He was not unprepared to hear that the reason why the latter experiment had been so much shorter than the former, was that the bars were considerably injured by the intense local heat generated by the blast. He was prepared to find that with those enormous blasts the bars would be injured, and if that were so it would be a reason for not anticipating that the weight of the boilers would be reduced by largely increasing, by those means, the rate of evaporation and the rate of combustion per square foot of firegrate, unless some means were adopted to preserve the bars while the fire was subjected to the action of the blast. Mr. Wright had given some weights relating to the "Polyphemus," and it was generally known that other vessels of a similar character were being built by the Austrian Government. Mr. Flannery should like to add that there were four cylinders in those engines, 28 inches in diameter, of 33 inches length of stroke, the number of revolutions being one hundred and forty, and the piston speed 770 feet per minute. There were five locomotive boilers made of steel, with copper fire boxes working at a pressure of about 100 lbs. per square inch. The indicated HP. was 2000. The weight was 225 tons, corresponding to 280 lbs. per indicated HP. Those figures, and the fact that the Austrian Government was moving in that direction, tended to show that other nations besides England were alive to the importance of deducing proper lessons from the results that had been obtained; and, if that was taken to heart by those who were dealing with a larger class of work than the author had dealt with, his paper would not have been written and read in vain. He hoped that he should not be misunderstood in what he had previously said, because he desired to bear testimony in the very strongest manner to the liberality with which the author had laid before the Institution the details of his work which hitherto had been kept secret.

Mr. Thornycroft, in reply, said he wished first to refer to the diagram of some experiments made on the "Miranda," and which were alluded to by Mr. White and Mr. Bramwell. The lower increase of power required for high speed was shown by the reduction of slip in the propeller, and the different value of the ordinates. Mr. Bramwell had remarked on the indicator diagrams taken at high speed, and he could only corroborate what Mr. Bramwell had said as to the reliability of diagrams of that high speed if they were made sufficiently small. Mr. Bramwell, had also called attention to the fact that in the locomotive boiler of first-class boats, a great part of the weight consisted of surface that was not productive. Mr. Thornycroft regretted that the surface could not be made productive. Mr. Bramwell had mentioned a kind of boiler which he said would probably save 2 tons in weight. The boiler, he believed, weighed a little over 5 tons, and the water nearly 2 tons. Of course, if they could utilize the whole of the surface for generating steam, and only have a light case to contain the products of combustion, the boiler would be lighter; consideration would be given to the suggestion, with a view of lessening the weight. He believed the total weight of the boiler and water was about one-half of the total weight of the machinery. Mr. Bramwell thought that by using high pressure the engines might be reduced in weight. Possibly that was so, but Mr. Crampton years ago recommended them not to depart from the present practice, because of the great trouble experienced in packing. He was not sure whether asbestos packing would get over the difficulty, but they had not ventured beyond 130 lbs.; 140 lbs. was used in locomotive practice, but the engines were not used in full power for any considerable time. Mr. Schonheyder had referred to jackets, and his opinion was that if the engines ran slowly the jackets would have time to work. He need hardly say that with torpedo boats they could not afford to run the engines slowly in order that the jacket might have time to do its work. Whether or not there was any advantage in the rings to which Mr. Schonheyder alluded he did not know. Mr. Dunell had referred to the Herreshoff boiler, and had mentioned that his firm was going to fit that boiler to two boats. That was the case, but he would not venture to prophesy what would be the result. As to the effect of the high center of gravity, which Mr. Bernays seemed to think an important feature, the weight of the cylinders in comparison with the whole weight was really so small that the height of the cylinders did not affect the stability much. Mr. Yarrow had asked what was the consumption of coal for long distances. His firm had not accurate information as to the consumption of coal for a long run, but in the first-class torpedo boats between London and Cherbourg they had found that at 11 knots the consumption was about 2½ tons. Mr. Yarrow had also spoken of the screw in the position used by Mr. Herreshoff, under the center of the boat; he thought that considerable loss was occasioned thereby. It did not appear to him that Mr. Yarrow had thoroughly appreciated the object with which Mr. Herreshoff had bent his shaft, which was to bring the screw about perpendicular to its work. The diagonal position of the screw had more effect than would appear at first sight. Taking an extreme case by way of illustration, if the axis of the screw were inclined to the line of motion 45°, that part of the screw blade which had a pitch of three diameters varied in pitch throughout the revolution, and the amount that it varied in the present case was from nothing to infinity. Mr. Barnaby had called attention to the stream line motion of the water about the boat, and stated that he did not know whether Mr. Yarrow had adapted the screw properly, and that if that was not done there would be a further loss. He had also referred to the subject of vibration, and said that a torpedo boat of 86 feet in length vibrated when the engine ran at two hundred, four hundred, six hundred, or eight hundred revolutions. Their experience with boats of this kind had been that there was no considerable vibration when the engines were running so slowly. In a boat of that size they found that the vibration was considerable when the engines attained a speed of three hundred and sixty or three hundred and seventy to three hundred and ninety revolutions, and that it began to diminish at four hundred. The strength of the boat had no doubt some influence on the result.

Mr. Yarrow had said that the only point in which he differed from the author was as to the advantage in placing the propeller before the rudder, and he had instanced the results of experiments in support of his argument in favor of this disposition. Mr. Yarrow appeared to think that there was some advantage in simply stopping the rotation of the water generated by the propeller; in fact he attributed to the rudder an action similar to that of a properly constructed guide plate. A flat rudder no doubt stopped the rotation of the water, but it was not possible to get any propelling action from a surface which was perpendicular to the motion of the vessel. Messrs. Rankine and Napier had patented a special form of rudder in which the blade was curved so as to take advantage of that transverse motion of water, but whether any distinct advantages had been obtained from it he had not heard. In the action of an ordinary propeller, where the blades were narrow in proportion to their length, measured at right angles to the axis, the water passing through the disc had rotary motion imparted to it, so that during part of the revolution the guide plates could be efficient, but during the other part they might be a positive resistance. It appeared to him that experiments on two boats of similar construction might give such results as could not be regarded as conclusive. In some models he had made, the guide plates and cylinders slid loosely on the shaft. Being aft of the propeller and prevented from revolving by a tangential wire, when they pulled forward they pressed against the propeller, and by a self-recording apparatus the whole thrust was taken—the thrust due to the guide plates less friction; because before the guide plates could exert any thrust upon the shaft they had to propel the tube and overcome their own resistance in the water. It was found that the effect which still remained due to the guide plates was about one-fifth of the whole propelling effect; the propeller was intended to do what the late Mr. Froude proposed to do with the paddle wheel. Mr. Froude had explained to him a form of paddle wheel he had proposed, and which impressed gradually on the water the motion to be given in propelling. If the water was started in an abrupt manner by a blow, the loss by slipping amounted to the whole speed of the slip; in other words the work was all done at the speed at which the water was finally discharged. But if the water could be impressed with motion gradually, the loss by slip would only amount to one-half the acceleration, and would be reduced to one-half that of the previous case if the final velocity impressed were the same in both cases. Mr. Froude proposed, in immersing the blade of a paddle wheel in the water, to give each blade a gradually increasing motion by proper mechanism, and he thought "this would not be difficult to devise" for the screw propeller. But he found that Mr. Bramwell's specification described the method of constructing paddle wheels in which gradual acceleration of the water was the chief aim, and Mr. Bramwell considered that better results might be obtained, and that possibly the same thing could be done with a screw. Mr. Froude did not appear to have arrived at any solution of the question for the screw propeller, but Mr. Thornycroft afterwards thought it could be done with a screw if a suitable channel could be made for the water to flow through. The water went into the propelling apparatus at the speed found at that part of the vessel, and the area should be so proportioned that the water would be discharged at the required velocity to propel the ship, the propeller gradually increasing the velocity. With the ordinary propeller, acceleration took place to a great extent before the water arrived at the propeller, and the propeller had to act in water running at the accelerated speed. The curious part of the result was that, with the propeller represented, when using twice the acceleration of the common propeller, and having only half the area of disc, about the same efficiency was obtained as that from an ordinary screw when working at its greatest efficiency.

With regard to the tubes of the boilers, they had, as Mr. Wright had explained, some unsatisfactory work. The tubes had leaked into the fire box, but that leakage, together with some priming, was almost the only trouble they had experienced. Iron tubes appeared to form a certain quantity of oxide in the water, producing a liability to prime. They believed that copper fire boxes gave more steam, but they did not consider that they were so strong as iron fire boxes. Mr. White thought that there were two obvious limitations to the extension of the torpedo system—the hull being very light and the load being very light. He considered that small hulls must be heavier than large ones, and he would prefer that the author should compare torpedo boats with tugs and small launches instead of with large vessels. Mr. Thornycroft thought that tugs and small launches were not suitable for comparison; the former were able to stand rough usage, and were intended to bump against larger structures; but torpedo boats were not designed for any such purpose. The hulls of the torpedo boats had been found amply strong, and had not given way under ordinary treatment. They had been perforated once or twice. On one occasion, in the dark, one torpedo boat ran into another at a considerable speed, and it would not be considered a surprising matter that one of them went right through the other; the bows of one boat were smashed, and the sides of the other were perforated. The water-tight compartments were intact, and neither of the boats sank; both floated without repair for about a day. At Cherbourg, where they had delivered some boats for the French Government, one of them ran into the dock wall at a speed of 12 knots an hour; the bows were smashed and the stokers and engineers were hurt by the sudden stop, but the boat still remained watertight and seaworthy. One of the English boats ran ashore at Malta, and her bows were smashed, but the machinery was not damaged, and the structure was not injured, except that part of the bow which was smashed. Mr. White appeared to think that small boats ought to be the heaviest. The strength of a boat only increased as the cube of her length. The vessels being similar, the stresses among the waves of the sea varied as the fourth power. To confirm the correctness of that statement he would refer Mr. White to a Paper by Mr. John on the strength of iron ships, read before the Institution of Naval Architects in 1874. "The tension per square inch on the upper works of a vessel of 3,000 tons appears to be once and a half as great as that on a 1,500-ton ship, twice as great as on a 700-ton ship, and five times as great as in a little vessel of 100 tons." The torpedo boats were not even 100 tons. Mr. White had asked if the hulls of the second-class boats were lighter than those of the first-class. They were lighter. In the paper they were stated at 30 per cent., the first-class being 33. As to durability, the author had built a boat containing some plates weighing only 1 lb. per square foot, or $\frac{1}{40}$ inch thick, and they had lasted twelve years. No doubt if they had been allowed to rust they would not have lasted so long; but such plates should not be allowed to rust. Mr. White considered that the hull was a mere shell carrying the machinery, but this was not so; it was divided by a number of efficient bulkheads and half bulkheads, which greatly increased the strength of the hull and lessened the danger of sinking. With respect to the load, high speed passenger vessels carried, he thought, even less load than torpedo boats. Mr. White appeared to think that the loss of speed due to the increased load was peculiar to torpedo boats. Of course, the diminution of load increased the speed of all vessels. In regard to the question of economy, he did not think that Mr. White had made a sufficient distinction between the engine and the boiler. The engines of the torpedo boats were compound, and they were economical in the quantity of steam used. The ratio of expansion perhaps was not so great as might be used where the cylinder capacity was not limited; but a further increase of cylinder capacity to allow a larger ratio of expansion, where only two cylinders were used, he did not think was a very great advantage. Mr. Crampton had said that the boiler could not be made economical; but where a particular service had to be performed, it was easy so to proportion the boiler and the fuel as to get the least combined weight of the boiler and the fuel. In those boats, of course, the fuel had only to be carried for a short distance. Mr. White thought that Mr. Thornycroft was surprised at the results obtained in the "Miranda." He had built the "Nautilus" in 1860, and at that time there were boats running on the Regent's Canal which had been imported from Lancashire, and these boats ran nearly on the wave. In building the "Nautilus," he had hoped to get the same result in a steamer, which was got by the canal boats. These were 6 feet wide and 60 feet long, and were propelled by two horses at the rate of about 9 or 10 miles an hour. The effect was that the water in the canal was very little disturbed at that high speed. The speed of the principal waves which accompanied the boat was limited by the small section of the canal. Where the same thing was attempted in open water, the circumstances were different. He had hoped in the "Nautilus" to accomplish that result. She ran in the University Boat

Race of 1862, at a speed of 11 or 12 miles an hour. In 1870 he had built a fast boat, the "Ariel," which had a light engine and a framing of wrought iron, and some plates in the hull $\frac{1}{40}$ inch thick. The boiler was subject to priming, and the speed of the boat was limited by the steam-generating power of the boiler. The speed actually obtained was 14 miles an hour, but the boat did not mount the wave. Mr. White wished to know how Mr. Thornycroft would apply in a moderate draught of water the large powers which he had succeeded in calculating to drive the "Iris" at 40 knots. Mr. White had estimated that it would take 45,000 HP. No doubt, he did not at the time think of the great advantage he was giving to the propeller. The members might be surprised at the smallness of the diameter of propeller which would give the best propelling effect. A propeller like that on the table had been fitted to Her Majesty's torpedo boat "Lightning;" the diameter of the tube was 3 feet, and at 18 knots 400 HP. was utilized to the best advantage. Two propellers, similar to the model for the "Iris," each 7 feet in diameter, would be required to use 45,000 HP. at 40 knots. Encouraged by Mr. White's remarks, Mr. Thornycroft had been induced to calculate what could be done in a moderate draught, and he had found that in the case of a large vessel going 50 knots, if two 20 feet diameeter guide plate propellers were used, they would be working at the best efficiency in utilizing 762,000 HP. Mr. Samuda had stated that he had been induced to use simple engines instead of compound, because of the increased weight of the compound. No doubt he had good authority for that statement, but he thought that in that case the limited number of revolutions allowed by the paddle wheels were the cause of the increased weight, the addition to the cylinders being greater than the reduction of the boilers by the change. It appeared however to Mr. Thornycroft that if paddles could be dispensed with and a propeller used which would allow the engines to be run at high speed, compound engines would undoubtedly have the advantage in reduced weight. Two guide-blade propellers on his design would only require to be each 5 feet 6 inches diameter for the power mentioned by Mr. Samuda, and a speed of 18 knots.

Mr. John wished to know what was the natural vibration of boats. The worst he was acquainted with was one instance in which there were two transverse sections of the boat that were nearly still, situated about one-third, or rather less, from each end; while each end and the center section had considerable motion, all of the same period, so as to cause a line intended to be straight in the length of the boat to be alternately convex and concave in a vertical plane. He was sure that boats did sometimes behave in that way, having distinctly felt the still places by walking along the deck. He had been interested to hear from Mr. John that sometimes there were double the number of oscillations at one end than at the other. Mr. John had taken exception to the language which he had used, and which was, perhaps, a little too general. Mr. John had shown a particular case in which the range of stability was lessened, but even in that example the greatest righting moment was increased. In the torpedo boat referred to, as the stability vanished before 90°, and as the added bulk was above the center of gravity when the boat was inclined to 90°, stability was added. He felt sure that at lower angles it was added, and therefore the range of stability was increased by that addition, so that the reasoning Mr. John had given for a cylinder loaded below its center and increased in bulk above did not apply to vessels having ranges of stability less than 90° from the vertical.

The question had been asked why jackets were not put on the second-class engines, and were put on those of the first class. It was desired in that instance to make larger engines without altering the patterns more than necessary, and the liners were taken out. The main bolts, the connecting rods, and the parts that required strengthening, were made larger, and the engines, although occupying the same bulk, had high-pressure cylinders 8 inches instead of 7 inches in diameter, and the low-pressure cylinders were also increased. The engines never had steam jacket covers, but if the engines were jacketed the covers ought to be jacketed also. That had been avoided on account of the weight;

but in order to make the covers strong they found that they necessarily became double, or nearly so. In more recent engines the covers and the bodies of the cylinders were jacketed. They had used a solid, square cast iron piston valve, working through a hole which fitted it accurately. He had thought that one of those valves would one day stick fast and cause the engine to break down, but that had not been the case. They had found that Perkins' metal rings wore away, and on the slide valve there was a fine bronze powdered dust, which seemed to have the effect of aiding the lubrication. They did not intentionally put any oil in the cylinders. Some oil got in at the piston rod and other glands, and then reached the boilers. They were going to try the effect of not putting oil on the piston rods. Captain Dawson had asked how many hours they could run at 20 knots an hour. He thought about four hours. With the boats tried at Cherbourg, they had guaranteed three hours at full speed—18 knots, and coal was carried for that purpose. Of course they could have carried coal for a greater distance. Mr. Spencer had inquired what margin of safety was found in the engines described in the paper. In the line shafting it was estimated that the streets at the surface did not exceed 12,000 lbs. per square inch; in the piston rods when under compression some part of the section might have a load equal to 12,400 lbs. per square inch, but when under tensile load it might be supposed that the stress was equally divided over the section, and it would not then exceed 6,500 lbs. per square inch in the cylindrical part of the rod. In the connecting-rod and in the main bolts a factor of safety of about 6 was used, and the practice was justified by the absence of accidents. With regard to the factor to be used in long shafts where a heavy propeller turned an equivalent to a fly wheel at one end, and the engines had a large moment of inertia at the other, the elasticity of the shaft, together with the unequal resistance of the screw during different parts of its revolution, and the irregular turning power of the engines during their revolution, were competent to cause much more stress on the material of the shaft than that estimated from the greatest turning moment the engines appeared capable of exerting. A shaft, in the circumstances described, would have a particular period of angular oscillation, and if this was the same as any considerable variation in the load, the shaft would probably break, although apparently not overloaded. The load on the steel shell of the boilers was about 8,300 lbs. on the reduced section, or about 6,000 lbs. on the gross plate per square inch of section.

It was the opinion of Mr. Flannery that the endurance of the fire bars had probably limited the duration of the evaporation experiments referred to. The author was not present, and could not therefore say, but he did not believe that was the case, as the fire bars would generally stand for a number of runs at full speed, and it was very unusual to have them interfere with an experiment. With regard to running engines at high speed, it was not customary to give large marine engines sufficient bearing surface to allow them to continue to run very fast, and the size of ports and passages were also not adapted to any considerable increase of speed without showing loss on the diagrams.

On the Manufacture of Magnets.—By G. Trouvé.—The author communicates the method by which he has attained success in the making of permanent magnets. Three points are observed: (1) To obtain the best steel, (2) to determine the degree of temper, (3) to select the most simple and practical process of magnetization. The tempering is effected in a gas muffle at a constant temperature. The magnetization results from placing the bars in two juxtaposed solenoids, the magnetic circuit being closed by two plates of soft iron; the current is obtained from a battery of 6 Wollaston elements. Magnets so made will carry twelve to fourteen times their weight; if the magnet is bent to a horseshoe, the charge is quadrupled, that is to say, the magnet will carry forty-eight to fifty-six times its weight. Magnets furnished with bobbins having 120 meters of No. 36 wire (0.1 millimeter in diameter) and a resistance of 240 ohms make very powerful Bell telephones.—*Comptes Rendus de l'Academie des Sciences.*

ON THE STRENGTH OF WROUGHT-IRON BRIDGE MEMBERS; INCLUDING STRUTS, COLUMNS, SEMI-COLUMNS, BEAMS, &c.

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Written to accompany Report to the Hon. H. SABINE, Commissioner of Railroads and Telegraphs.

(Read before the American Society of Mechanical Engineers.)

II.

GENERAL APPLICABILITY.

All expressions for the moment M, from equation (17) to (79) inclusive are applicable in equations (6) and (8), the former giving the strain t_1, due to the bending moment alone, and the latter the total or max. strain t, in the section considered. Any section throughout the length of the beam may be examined for strain, but usually the section under maximum strain is the one to be attended to.

It is to be observed that the strain due to M, is not in any case of the existence of T to be taken as the only strain. That due to T directly, according to (7), is to be included. For instance, points of contrary flexure are usually regarded as locating sections which are free from all strain except "transverse shear." But in all cases of points of contrary flexure mentioned above there will be not only transverse shear, but direct longitudinal tension or compression also. Hence the resultant stress will in these cases be diagonal in direction.

It is to be observed that T and t have been universally employed both for tension and compression. This was simply for convenience. In application, the proper distinction is to be made.

In cases where T is compressive in the above expressions for M, the beam may be regarded as acting partly like a beam and partly like a column, and we may vary the intensity of action from one almost purely of the first kind to one of the second kind.

ORDINARY BEAM FORMULAS

But at the limit $T=o$ some difficulty is experienced as, for instance (77) reduces to $\frac{0}{0}$ for $T=o$. But let the tangent be developed into a series, thus:

$$M_{max} = \frac{Q}{2n}\text{tang } n\frac{l}{4} =$$

$$\frac{Q}{2n}\left\{n\frac{l}{4} + \frac{n^3}{3}\left(\frac{l}{4}\right)^3 + \frac{2n^5}{15}\left(\frac{l}{4}\right)^5 + \&c\right\}$$

$$= \frac{Q}{2}\left\{\frac{l}{4} + \frac{n^2}{3}\left(\frac{l}{4}\right)^3 + \&c\right\} \quad . \quad . \quad (80).$$

or

$$M_{max} = \frac{Ql}{8} \text{ for } n=o \quad . \quad . \quad . \quad (81).$$

This is the same expression for the maximum moment of flexure as we find given in works on the strength of beams for the case of a beam fixed at the ends and a load Q at the middle; conditions identical with (81) where $T=o$.

Similarly, (78), by expanding the $\cot n\frac{l}{2}$ gives

$$M_{max} = P_1 r = -\frac{w}{n^2} + \frac{wl^2}{12} + \frac{wn^2l^4}{720} + \&c + \frac{w}{n^2}$$

$$= +\frac{wl^2}{12} \text{ for } n=o \quad . \quad . \quad . \quad (82).$$

which is also the same as given for this case.

Making use of the expanded series for e^x, expressions (72) and (73) will reduce also to (81) and (82). The other expressions of moment above may be likewise reduced for $T=o$, to the ordinary well-known formulas.

Thus it appears that the above equations and formulas are general, and the possibility of reducing the same to the ordinary expressions for simple cases corroborates all the circuitous mathematical work.

FORMULAS FOR COLUMNS, PILLARS, STRUTS, ETC.

In cases where the force T predominates, the piece acts mostly like a column. Passing to the limit by making the transverse forces zero, we have form (24):

$$\frac{-Ty_1-Pl}{\text{tang } nl}=\frac{P}{n}$$

or

$$=\frac{Ty_1}{\text{tang } nl}=0$$

if $P=o$. But as we propose that T shall be the predominating force applied to the piece, then $T\,y_1$ cannot be zero unless $y_1=o$, and the latter cannot be assured since T may produce considerable deflection to one side or the other. Theoretically there would be no deflection, but we know that practically there would be a very appreciable deflection for a piece of ten to twenty or more diameters in length before rupture; hence, we must treat the case as providing for a deflection, y_1.

Hence it appears that the denominator must be infinite, which requires that

$$nl=\frac{\pi}{2}$$

or, since $n^2=T\div\varepsilon I$

$$\frac{T}{\varepsilon I}=\frac{\pi^2}{4l^2} \quad . \quad . \quad . \quad (83).$$

for a column fixed at one end and free at the other, as in Fig. 17.

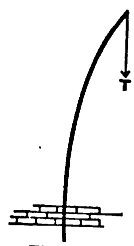

Figure 17.

The same result is obtained from (31). This expression (83) is given in several works, and produced in different direct ways.

Equation (49), for $Q=o$, requires, for like reasons, that $\text{tang } n\frac{l}{2}=\infty$

or

$$n\frac{l}{2}=\frac{\pi}{2}$$

$$\therefore \quad \frac{T}{\varepsilon I}=\frac{\pi^2}{l^2} \quad . \quad . \quad . \quad (84).$$

This expression is also obtained from (58), and is for columns having rounded ends; or, more specifically, pointed bearings. This expression is also given in several works on the strength of beams

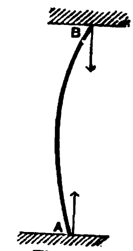

Figure 18.

obtained usually by a direct process. By some the column is said to have rounded ends for this formula, while others do not say whether the ends should be rounded, flat, or otherwise; that is, whether the end of the column is fixed or hinged, &c. The manner of holding the end, however, is not a matter of indifference, equation (49) showing that (84) is for rounded or hinged ends as shown in Fig. 18.

Equation (77) or (78), for Q or $wn=o$ and T not, requires that

$$\text{tang}\frac{l}{4}=\infty \text{ or } n\frac{l}{4}=\frac{\pi}{2}$$

or that

$$\cot n\frac{l}{2}=\infty \text{ or } n\frac{l}{2}=\pi$$

either of which gives

$$\frac{T}{\varepsilon I}=\frac{4\pi^2}{l^2} \quad . \quad . \quad . \quad (85).$$

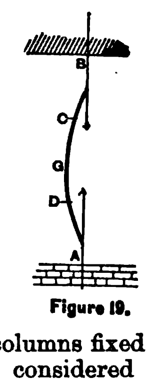

Figure 19.

which is for columns fixed at both ends, or sometimes considered as having flat ends, as shown in Fig. 19.

This expression is not common in published works as applying to columns with fixed ends. An article of much merit which appeared in VAN NOSTRAND'S ENG. MAG., Vol. 17, p. 257, gives the above equation (84), but does not state whether the columns are for round or flat ends except as indicated by a figure like Fig. 18. But later articles in VAN NOSTRAND'S MAG. by J. D. Crehore and Prof. Baldwin give both (84) and (85,) also (87) with statement of end conditions.

To obtain the expression for a column having one end fixed and the other end rounded, we naturally turn to case XI, above. But the deduction of a satisfactory expression from this is difficult. However, reasoning from analogy, compare Figs, 18 and 19 with their expressions. Thus,

$$\left.\begin{array}{l}\text{For Fig. 18, } nl=\pi \\ \text{For Fig. 19, } nl=2\pi\end{array}\right\} \quad . \quad . \quad . \quad (86).$$

Observing that the curves are sinusoids—see eqs. (22) for $h=o$ and (47.)—we find AB, Fig. 18, like c D. Fig. 19, both being complete flattened sinusoids. But the middle of the beam at G, Fig. 19, is parallel to the same at A or B; from which we conclude that

$$AD+BC+CD=2 \text{ sinusoids.}$$

Hence the number of sinusoids in the curves Figs. 18 and 19 agree with the coefficients to π in the respective expressions (86).

Now for a column which has one end flat and the other rounded, the part CDA, Fig. 19, would represent it nearly, the chief point of difference being in the fact that C, Fig. 19, is not quite on the line of action AB. Assuming that the point D does not essentially change position as C is brought to the action line, then we can safely adopt $\frac{3}{2}$ as the coefficient to π for the expression corresponding to (86), because in Fig. 18 we have one sinusoid; in B, Fig. 19, two sinusoids, and in CDA $\frac{3}{2}$ sinusoids.

Now the point C, Fig. 19, is a point of contrary flexure, or a point where the bending moment is zero, and hence the condition of CDA would not be altered by cutting off the column at c and rounding it, thus giving, in CDA, a column with the desired conditions.

Hence the expression

$$nl=\frac{3}{2}\pi$$

or

$$\frac{T}{\varepsilon I}=\frac{9}{4}\frac{\pi^2}{l^2} \quad . \quad . \quad . \quad (87).$$

for the case of columns having one end flat or fixed, and the other rounded or pointed.

The conditions are shown in Fig. 20,

Figure 20.

where A is fixed, and B rounded or hinged.

These formulas, (83) and (84), have been proposed for use by some writers, without modification, though apparently with much hesitation and doubt; others have declared them wholly unfit. It appears that Hodgkinson compared (84) in the form

$$T=\varepsilon\pi^2\frac{I}{l^2}=\frac{\varepsilon\pi^2}{64}\cdot\frac{d^4}{l^2}$$

where

$$I=\frac{\pi d^4}{64}$$

with his experimental results, but finding it discordant, only used it as suggestive of form for an expression for columns, thus:

$$W=C\frac{d^n}{l^m} \quad . \quad . \quad . \quad (88).$$

where W= wt. sustained, d = diameter, l length; and with C, m and n, constants to be determined by experiment. The differences made manifest by Hodgkinson's experiments between (84) and (88), as to the values of m and n, are such, except by further inquiry, as to destroy all confidence in (84) as a formula to use directly in calculating the strength of columns. The same is true of (85) and (87.) This is unfortunate as regards one important fact, viz: (84) contains the moment of inertia of the cross section instead of merely the diameter, so that (84) may be applied to any form of section, such as round, square, oblong, I and H sections &c., while (88) must be prepared for each characteristic section. Also, (84) contains one important factor, ε, which qualifies that formula for at least this one property of the material going into the column. But evidently there is, at least, one other property which is equally important, viz: the crushing resistance; or, if preferred, the elastic limit, neither of which appears in (84). Hence, though (84) has some valuable features, it must be pronounced sadly deficient as a general formula, except possibly for very long columns, such as would fail by simply springing out, without breaking. But evidently columns relatively short, though longer than "blocks," and such as would fail partly by crushing and partly by springing, should have a formula containing both the coefficient of elasticity ε, and some modulus of resistance, such as t, for compression or tension, usually the former. Again still shorter columns or "blocks" would only require the modulus of crushing resistance.

Let Fig. 21 represent a portion of a

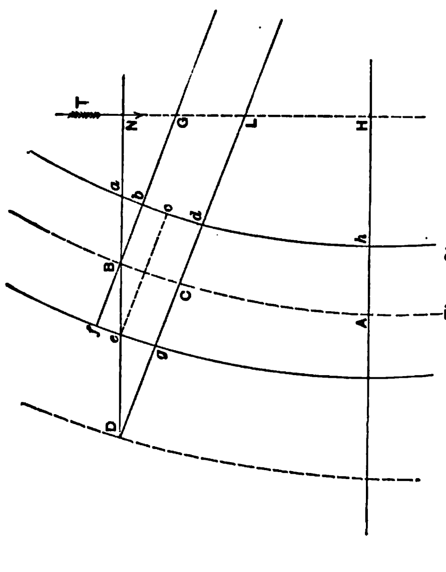

Figure 21.

column under strain from the action of T, the strain being partly compressive and partly flexural.

To formulate the relations between these actions, suppose AB, Fig. 21, to be a unit's portion of a column near its middle, which is sprung out of its original axial position NGH, to AC, the original axial fiber HN being now shortened and deflected to AC. The section dg was before flexure on the line ae, the intersection at D being a point on the real neutral axis of the column. The distance along DC to the intersection with AH, is the radius of curvature ρ. Draw BG parallel to DC, intersecting AH. The distance from this latter point to B is equal to ρ, because of the parallelism of BG and DC.

Then, according to (5), taking the line GH as the axial line of the column previous to flexure, and the line along which the compressive force T still acts, we will have the applied bending moment equal

$$\frac{\varepsilon I_1}{\rho} = Ty_1 \quad . \quad . \quad . \quad (89).$$

where I is the principal moment of inertia, or monent of intertia, for an axis perpendicular to the plane of the curve ACB, at the center of gravity B of the section considered; y_1=BN, the moment arm of T, and ε, the coefficient of elasticity.

This supposes that the ends of the column remain in the same position while the body deflects to one side or the other, as it will do in columns of considerable length before rupture—a fact known by experience. Hence the column is represented as deflected to one side in order that the conditions of the problem may coincide with experience. Equation (89) applies evidently to any unit length of the column if y_1 be supposed to be the ordinate to the axis for that point, and this without regard to conditions outside of that unit portion. It applies whether the column be fixed, rounded or otherwise, at the end, or even if the column be bellied. But the ordinate y_1 will be different for intermediate portions as depending on form of body of column as to taper, belly, &c., from which it appears that a bellied column will support differently from a prismatic one. Our analysis applies to the latter. The ordinate is marked y_1 instead of y, to distinguish it as the maximum ordinate to the axial curve of the column; that ordinate being chosen because the moment of T is here greatest, and hence may denote the ordinate at the rupturing point of the column.

In (89) the 2d member is the applied moment, and is that which simply bends the column. The 1st member is the moment of resistance to this bending, and represented in the figure by the triangle B*ab* of compression, and B*ef* of tension.

To obtain another equation take the origin of moments at D on the real neutral axis. Then the total moment of resistance is

$$\frac{\varepsilon I}{\rho}=T\,(y_1+BD)\quad . \quad . \quad . \quad (90).$$

where I is now the moment of inertia of the section at B for an axis at D; (y_1+BD) the moment arm of T; and ρ the same as in (89), as already stated. By a well-known formula, we have

$$I=I_1+K.\overline{BD}^2$$

B being the center of gravity of the section.

Introducing I, we have from (90),

$$\frac{\varepsilon I}{\rho}=\frac{\varepsilon I^1}{\rho}+\frac{\varepsilon}{\rho}K\overline{BD}^2=Ty_1+T.BD$$

or, by (89)

$$\frac{\varepsilon}{\rho}K\overline{BD}^2=T.BD\quad . \quad . \quad . \quad (91).$$

But calling the shortening $BC=\lambda$, we have

$$\lambda : BD :: 1 : \rho$$

whence

$$\frac{BD}{\rho}=\lambda$$

and (91) becomes

$$\varepsilon K\lambda.BD=T.BD\quad . \quad . \quad . \quad (92).$$

But from the fundamental law of elasticity, see eq. (4½), observing that the shortening $BC=\lambda$ is for a unit length

$$T=\varepsilon K\lambda.$$

Combining this with (92), it becomes an identical equation which proves its correctness.

To determine the practical limitations of the ordinate y_1 let T be applied at E, Fig. 22, to a prism of unit's length. First, let the distance, BE, = the *principal radius of gyration*, $=k$. The point B is the center of gravity of the section at ED, or top of the prism. Now, as T is applied at E, let an equal and opposite force be applied at B, as shown. We thus have a couple acting to turn the top surface of the prism around B from the line EBD to FBH. If now we remove the counteracting force at B, while T is kept constant, the point, B, will fall by the compressive action of T to some point C. Call $BC=\lambda$. This will be found $=EF$, when $BE=k$. For we have, by taking moments at B,

$$Tk=\frac{\varepsilon I_1}{\rho};\ \text{also}\ I_1=Kk^2,\ \text{and}\ T=\varepsilon K\lambda$$

combining,

$$\frac{T}{\lambda}\frac{k^2}{\rho}=Tk\ \text{or}\ k=\rho\lambda$$

whence

$$\rho : 1 :: k : \lambda,\ \text{or} : BC$$

Hence $\lambda=BC=EF$ as proposed.

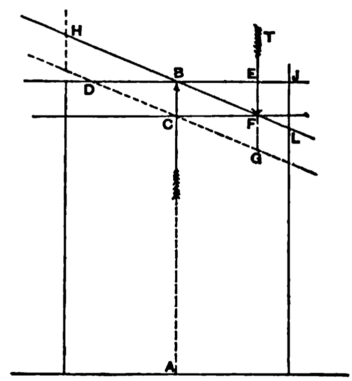

Figure 22.

Applying T at any other point, we have a different result, for suppose it at J. The compressive effect, BC, will be the same for the same value of T as long as it is the only compressive force. But the fall due to bending will be greater, even greater than JL, because the moment arm is greater.

Hence when a compressive force, T, is applied at the distance, k, from the center of the cross section of a prism, the displacement, EF, due to bending is exactly equal to the displacement, FG, or BC, due to direct compression.

Next suppose the neutral axis to be taken at a distance qk from B while T is applied at E. Then eq. (90) gives

$$T(k+qk)=\frac{\varepsilon I}{\rho}=\frac{\varepsilon I_1}{\rho}+\frac{\varepsilon}{\rho}K(qk)^2$$

or $$\text{since}\ Tk=\frac{\varepsilon I_1}{\rho}\quad . \quad . \quad . \quad (92a).$$

$$Tqk=\frac{\varepsilon K}{\rho}q^2k^2$$

$$Tk=\frac{\varepsilon K}{\rho}qk^2 <=\text{or}> \frac{T}{\rho\lambda}k.qk$$

where $\rho\lambda = k$ when T is applied at E, and $T = \varepsilon K\lambda$

Hence

Tk = applied moment

$<=$ or $>$ moment of resistance.

To make the first and second members equal, we must put $q=1$; and hence we must also have the neutral axis at a distance, k, from the center, B, of the section, for the condition that the column is indifferent as to whether it deflects more or less. If it deflects more, y_1 or BE, becomes $>k$, and $BD<k$, or $q<1$, and then the greater the displacement the greater is $BE=y_1$, and hence the greater the deflection of the column, Fig. 21, beyond $y_1=BE=k$, the greater is its tendency to deflect, because the applied moment becomes greater than the moment of resistance. But, on the other hand, when the ordinate, $y_1=BE$ is less than k, BD is greater than k, $q>1$, and the column is stable. It appears, therefore, that Tk is the greatest admissible applied moment. We, therefore, follow the condition that in eqs. (90) to (92), $BD=y_1$.

Now in Fig. 21, we have

$$ad : (BD+d_1) :: 1 : \rho$$

or

$$ad = \frac{y_1+d_1}{\rho}$$

and

$$\varepsilon . ad = t$$

where $BD=y_1$ $d_1=Ba$ = distance from the center of gravity of the section to where the fiber ruptures by compression, and t the greatest admissible compressive force per square inch for a unit's length of prism.

$$\therefore \quad ad = \frac{t}{\varepsilon} = \frac{y_1+d_1}{\rho} \quad . \quad . \quad . \quad (93).$$

But combining

$$\frac{\varepsilon I_1}{\rho} = Ty_1 \quad . \quad . \quad . \quad (94).$$

with equations (84), (85), and (87), observing that I is the same as I_1 in (94), we get for columns

$$\left.\begin{array}{ll} \text{with round ends} \ldots & \frac{1}{\rho} = y_1\frac{\pi^2}{l^2} \\ \text{with flat ends} \ldots\ldots & \frac{1}{\rho} = 4y_1\frac{\pi^2}{l^2} \\ \text{with round and flat} & \frac{1}{\rho} = \frac{9}{4}y_1\frac{\pi^2}{l^2} \\ \text{with fixed and free} & \frac{1}{\rho} = \frac{1}{4}y_1\frac{\pi^2}{l^2} \end{array}\right\} \quad . \quad . \quad (95).$$

Combining these with (93), we obtain

$$\text{for round ends} \frac{tl^2}{\varepsilon\pi^2} = y_1^2 + d_1y_1$$

or, solving for y_1

$$y_1 = \frac{d_1}{2}\left(\sqrt{1+\frac{4tl^2}{\varepsilon d_1^2\pi^2}}-1\right) \quad . \quad (96).$$

But by eq. (8), the total compression on the critical fiber ah, Fig. 21, is

$$t = Ty_1\frac{d_1}{I_1} + \frac{T}{K} \quad . \quad . \quad . \quad (96a).$$

or, introducing y_1 from (96)

$$t = \frac{T}{I_1}\frac{d_1^2}{2}\left(\sqrt{1+\frac{4tl^2}{\pi^2\varepsilon d_1^2}}-1\right) + \frac{T}{K}$$

and the remaining equations in (95) may be treated similarly.

Solving for the load, T, borne by the column, we obtain the following general formulæ, viz.: for columns with

Round ends

$$T = \frac{tK}{1+\frac{Kd_1^2}{2I_1}\left(\sqrt{1+\frac{4tl^2}{\pi^2\varepsilon d_1^2}}-1\right)} \quad . \quad (97).$$

Flat ends

$$T = \frac{tK}{1+\frac{Kd_1^2}{2I_1}\left(\sqrt{1+\frac{tl^2}{\pi^2\varepsilon d_1^2}}-1\right)} \quad . \quad (98).$$

Flat and round

$$T = \frac{tK}{1+\frac{Kd_1^2}{2I_1}\left(\sqrt{1+\frac{16}{9}\frac{tl^2}{\pi^2\varepsilon d_1^2}}-1\right)} \quad . \quad (99).$$

Fixed and free

$$T = \frac{tK}{1+\frac{Kd_1^2}{2I_1}\left(\sqrt{1+\frac{16tl^2}{\pi^2\varepsilon d_1^2}}-1\right)} \quad . \quad (100).$$

We observe that in using the equations (84), (85) and (87), our object is to obtain a relation between ρ and y_1, as given by the curves of sines of the elastic axes of the respective columns, and not to employ them as the foundations for the general formulas, because the latter object is found in (93), (94) and (96a), which give the limiting ordinate, y_1 the moment of flexure, and the limiting strain respectively.

In these formulas t is the greatest admissible compression per square inch, or the modulus of crushing, for breaking loads, K, the sectional area of the column at the middle, d_1 the distance from the center of gravity of the section to the fiber which ruptures first, I_1 the moment of inertia for an axis at the center of gravity of the section, and at right angles to the plane of the axial curve of the deflected column; l, the length of the column, and ε, the coefficient of elasticity of the material. Also we have

$$\frac{K}{I_1}=\frac{1}{k^2}$$

where k is the principal radius of gyration.

These formulas are readily adapted to special forms of section. For instance, for solid cylindrical columns with diameter$=2r$, (97) becomes, for rounded ends,

$$T=\frac{\pi r^2 t}{1+2\left(1+\frac{4tl^2}{\varepsilon r^2\pi^2}\right)^{\frac{1}{2}}-2}$$

But it is useless to make these adaptations since the present practice in designing bridge struts requires formulas which will be applicable to all conceivable forms of built struts or columns, such as combined I beams and channel bars, latticed channel bars, &c.

A Simplified or Approximate Expression.—In cases where the length of the column divided by the diameter is relatively small, the radical part of the denominator may be developed into a series, by aid of the binomial theorem, for a more convenient expression. In doing this, let us adopt one expression in common for (97), (98) and (99), by placing the numerical coefficient under the radical equal to a, leaving the general expression for it to be determined later. Also, introducing the principal radius of gyration, k, we have

$$T=\frac{tK}{1+\frac{d_1^2}{2k^2}\left\{\left(1+\frac{atl^2}{\varepsilon d_1^2\pi^2}\right)^{\frac{1}{2}}-1\right\}} \quad . \quad (101).$$

Now by placing

$$v=\frac{atl^2}{4\pi^2\varepsilon k^2} \text{ and } z=\frac{k^2}{d_1^2} \quad . \quad . \quad . \quad (102).$$

we obtain, with the developed denominator,

$$T=\frac{tK}{1+v-v^2z+2v^3z^2-5v^4z^3+\&c} \quad . \quad (103).$$

Now, in examining this equation, we find that for very short columns, we only need to retain $1+v$, and the formula then appears independent of d_1, which indicates reasonably enough that a column failing almost entirely by crushing, might have d_1 reckoned in one direction about as well as in another, for the distance from the center of gravity of the failing cross section to the point of incipient rupture; that is, for crushing on all sides the direction for d_1 is indeterminate, and d_1 as such, is not required.

For lengths somewhat greater, additional terms will be required for the denominator; but eventually, for considerably increased length, the denominator converges too slowly, requiring us to fall back upon the undeveloped denominator.

Special Simple Formula for Unusually Long Columns.—But at length we find a limit where the expression (101) will give the same value for the supporting power of the column as the corresponding simpler expression of (84), (85) or (87), which contain no factor for crushing resistance. Beyond this limit, the latter may be employed without hesitation, and failure will be expected to occur by springing instead of crushing.

To obtain an idea of the position of this limit, the ratio of length to diameter has been computed for solid cylindrical wrought iron columns and found to be for columns with

ends rounded .... $\frac{l}{d}=36.2$

ends flat.............. $\frac{l}{d}=72.4$

ends round and flat.... $\frac{l}{d}=54.6$

For square, hollow and open-built columns, the ratios are still greater.

Hence, these last named formulas, previously rejected, now return to us again for application to very long columns. For this purpose, fortunately, the objection to these formulas, previously stated, of the absence of the modulus of crushing, t, has no weight, because failure occurs by springing and not by crushing.

Criterion for Long Column Formula.—Evidently this limit is to be found by placing the values of the load T as given by the two formulas equal to each other, and then solving for the

$$\text{limiting ratio}\frac{l}{d}$$

For rounded ends we have therefore

$$T=\varepsilon I\frac{\pi^2}{l^2}=$$

$$\frac{tK}{1+\frac{Kd_1^2}{2I_1}\left(\sqrt{1+\frac{4tl^2}{\varepsilon\pi^2 d_1^2}}-1\right)} \quad . \ (104).$$

To avoid multiplying the solutions, it is desirable to obtain one which includes the three conditions of ends rounded, ends flat, ends round and flat. This may be done by aid of a, which is $=4$ in (104). To adapt a coefficient for the first member we observe that $\frac{4}{a}$ is sufficient. To provide for the fact that d_1 and the radius of gyration k do not bear a constant ratio to each other, for all columns, assume

$$\frac{d_1}{k}=\beta$$

Then, observing that k^2 is equal, the moment of inertia divided by the section, we have by introducing a and β,

$$\frac{T}{K}=\frac{4\varepsilon\pi^2}{a\beta^2}\frac{d_1^2}{l^2}=$$

$$\frac{t}{1+\frac{\beta^2}{2}\sqrt{1+\frac{atl^2}{\varepsilon\pi^2 d_1^2}}-\frac{\beta^2}{2}} \quad . \ (105).$$

an expression in which the first member, placed equal $\frac{T}{K}$, will give any one of the expressions (84), (85), or (87), by introducing proper values of a and β. Also the second member of which will give (97), (98) or (99), with like attention to a and β.

Clearing of fractions we obtain

$$\sqrt{1+\frac{atl^2}{\varepsilon\pi^2 d_1^2}}=\left(1-\frac{2}{\beta^2}\right)+\frac{atl^2}{2\varepsilon\pi^2 d_1^2}$$

Squaring, and solving for $\frac{l^2}{d_1^2}$, we obtain

$$\frac{l^2}{d_1^2}=\frac{4}{a\beta}\left(1+\frac{1}{\beta}\right)\frac{\varepsilon\pi^2}{t} \quad . \ . \ . \ (106).$$

a formula which serves as the criterion of applicability for $\frac{T}{K}=$ first part; or$=$ second part of (105), as a formula for extremely great or for ordinary lengths, respectively.

When the axis for the moment of inertia is an axis of symmetry for the cross section, we have $2d_1=d=$ whole diameter of column. This is the thickness in this case in the direction of the plane of the curve of flexure of the column, and is the extreme thickness, whether the column be solid, hollow or open-built.

When the cross section is thus symmetrical, we have

$$\frac{l}{2d_1}=\frac{l}{d}=\pi\left\{\frac{1}{a\beta}\left(1+\frac{1}{\beta}\right)\frac{\varepsilon}{t}\right\}^{\frac{1}{2}} \quad . \ . \ (107).$$

As an example, in cylindrical columns, d_1 is the radius of the column, and k the radius of gyration.

$$\frac{d_1}{k}=2=\beta$$

and for flat ends,

$$a=1$$

Taking $\varepsilon=28{,}000{,}000$ and $t=40{,}000$, we obtain from (106) or (107) the value 72.4, the same as given above.

FORMULA FOR END CONDITIONS.

Let us now determine a general expression for the qualifying factor a, an expression which shall duly qualify the general column formulas (105) for the case of fixed ends, flat ends, or of rounded ends (pointed); or for pin ends with large pins under friction, or for flat ends which are narrower than the middle section, or for one of these forms at one end, and another at the other, &c.

From (97), (98), and (99), we already have

For pointed ends....$a=4, m=o$
For fixed ends......$a=1, m=2$ (108)
For pointed and fixed.$a=\frac{16}{9}, m=1$

where m stands for the moment effect of the end conditions preventing lateral displacement of column at the middle. In Fig. 23, the pointed ends a and b offer no hindrance to the side deflection of the middle, m, of the column, hence in (108) m is zero. But at c and d, there is the stiffeners of the fixed ends, to prevent the middle from deflecting; and hence for this case in (108), $m=2$, similarly for the third part of Fig. 23, and of (108) $m=1$.

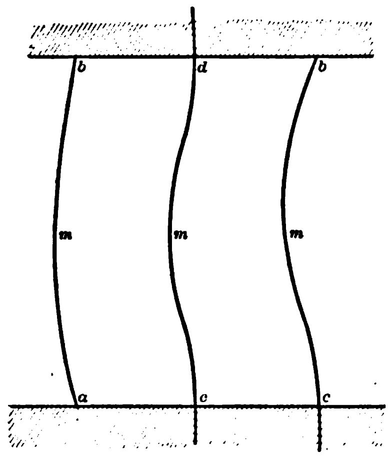

Figure 23.

Fixed Ends.—Now if we consider the stiffness at a fixed end as equivalent to a moment $p\frac{l}{2}$ preventing lateral displacement of the middle, we may combine it with the end and middle moments due to T as follows:

The expression Tk, see (92*a*), appears to be the max. admissible moment of flexure at the middle. Using a similar expression for the end, we have

$$p\frac{l}{2}=Tk'$$

where k' is different from k when the fixed end of column differs in size and form from the middle section. Designating the latter, or radius of gyration of the middle section by k_m, and of the end surfaces or sections by k_c and k_d, we will have the total counteracting moment

$$\frac{\left(p\frac{l}{2}\right)}{Tk_m}=\frac{Tk_c+Tk_d}{Tk_m}=\frac{k_c+k_d}{k_m} \quad . \quad (109).$$

an expression which admits of any size of end sections less than the middle section. Even the ends c and d may differ. Now we find by trial that a may be obtained from the expression

$$a=\frac{4}{\left(1+\frac{k_c+k_d}{2k_m}\right)^2} \quad . \quad . \quad . \quad (110).$$

for ends actually fixed.

To illustrate, if k_c and k_d are zero, $a=4$ as for pointed ends, thus producing (97) from (105) as regards qualifying with respect to a. Again put $k_c=k_d=k_m$ and $a=1$, as for (98). Finally for $k_c=k_m$ and $k_d=o$, we have $a=\frac{16}{9}$ as required in (99).

But suppose the ends are only half as large as the middle and similar. Then $k_c=k_d=\frac{1}{2}k_m$ and a becomes $\frac{16}{9}$, the same as for one end pointed and the other as large as the middle, and fixed.

To distinguish between actual fixed ends, and flat ends, it appears that in the former the column cannot fail at the end without a similar failure at the middle. According to the conclusion $BD=y_1$ in Fig. 22, there must be some tension in the section both at the middle and end of column. That is; the neutral axis is at D when rupture takes place, and outside of D there will be tension. Hence when the end sections are cut as in flat ends; that tension cannot act, and the column is weaker than for actual fixed ends. It appears therefore that the neutral axis should not approach the axis of the flat ends nearer than the outermost surface of the column. As the neutral axis is at D, where BD=the radius of gyration, k; we may obtain in flat ends, the equivalent to fixed ends, by making the radius of gyration of the flat end surface of the column equal to d_1. This necessitates enlarged, or disc-like ends.

Equation (110) is supposed to meet the real case of fixed ends. To adapt it to the case of flat ends, it is only necessary to replace k_m by d_1: because the same value of a would then be given by (110) thus modified for k_c and $k_d=d_1$, as would now be given by (110), as above, for k_c and $k_d=k_m$. That would make the radius of gyration of the flat end bearing $=d_1$ and the neutral axis could not approach the axis at the end of the column nearer than d_1. Then there would be no tendency to tension in the flat ends, as well as no power to resist it.

Again in built columns it is often the case that thickening pieces are laid on at the ends, thus making the area of the flat ends greater than the sectional area at the middle. From analogy with the usual relation of k and K in sections of beams, it appears that the radii of gyration k_c, k_d and d_1, should each be multiplied by the square root of the proper section.

Hence, to include the two modifications of (110) now considered, it appears that the equation (110) should be written.

$$a=\frac{4}{\left(1+\frac{k_c\sqrt{K_c}+k_d\sqrt{K_d}}{2d_1\sqrt{K_m}}\right)^2} \quad . \quad (110a).$$

The meaning of the subscripts is indicated in Fig. 23.

When the end surfaces or sections in every way equal the middle section of the column, the capitals, K, divide out and disappear, also when the ends are actually fixed d_1 should change to k_m and thence (110a) returns to (110).

When the flat ends are unenlarged, either in diameter or section, the capitals disappear; but d_1 remains and the denominator of (110a) is smaller than of (110), which makes the strength of columns with unenlarged flat ends less than that for fixed ends, which is evidently as it should be.

In no case should (110a) ever be used when the denominator gives a value greater than the denominator of (110).

Pin Bearings.—The pin bearing for the end mounting of a column is usually considered as acting in effect like a knife-edge terminal to the column. But it is evident at once that the friction of the pin must cause the column to act as though the end had some breadth which is appreciable, and hence not to be ignored. To provide for this, let r be the radius of the pin, and f the coefficient of friction.

Then, as the column bows to one side or the other, the point of bearing of the hole upon the pin will be thrown to one side a distance ox Fig. 24, which distance is greater or less according to the value of f. Now as is well known, the value of ox is

$$ox=fr.$$

By Fig. 23, this may be designated as fr_a or fr_b, as to whether it is expressed for one pin or the other.

In moment effect this is to be treated as an arm for T, so that the Tfr here, corresponds with Tk in respect to the fixed end. Hence, according to (109), we may write

$$\frac{\left(p,\frac{l}{2}\right)}{Tk_m}=\frac{fr_a+fr_b}{k_m}$$

a quantity which is of the same kind as (109) and may be incorporated in (110*a*) thus

$$a=\frac{4}{\left(1+\frac{k_c\sqrt{K_c}+k_d\sqrt{K_d}}{2d_1\sqrt{K_m}}+f\frac{r_a+r_b}{2k_m}\right)^2} \quad . \; . \; . \; (111).$$

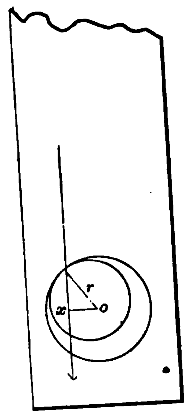

Figure 24.

In bridges, the pin is of considerable size, and the coefficient of friction quite high; probably between $f=.2$, to .3 for new bridges, and as high as .5 for older ones.

To illustrate, suppose the pin to be 4 inches in diameter at a and b. Then $fr = fr_b = .25\times2''=.5''$, or $=\frac{1}{2}$ inch.

If the column be a solid cylinder, 8 inches in diameter at the middle $k_m=2''$; and observing that k_c and k_d are both zero here, we have

$$a=3.16$$

As ordinarily treated, this would be taken as 4 instead of 3.16.

Relative Positions of Pin Bearings.—Now with respect to knife-edged *vs.* pointed ends, it is evident that when the knife edges are in one plane, and so oriented as to admit of deflection in the same direction as when the ends are pointed, the supporting power of the column is the same for either form of end. But when the knife edges are in a plane at right angles to the plane of deflection for points, the strength of the column is greater. This is with the understanding that the moment of inertia of the middle section is greater for an axis in one direction than in another. With a given cross-section of column the greatest strength with pin bearings is obtained by placing the knife edges parallel to the axis for that max. moment of inertia of that cross section. For deflections constrained by guides to be in the line of the knife edges, the strength is as for a column with flat ends. When a knife edge is placed at each end of a column, the strength is increased by placing the knife edges at right angles to each other. But for this hypothesis it is difficult to calculate the real strength of the column, or to determine the direction of the deflection.

To investigate this let us first take the first part of eq. (105). Replacing β by its value we have for the supporting power per square inch

$$\frac{T}{K}=\frac{4\varepsilon\pi^2}{a}\cdot\frac{k^2}{l^2}=t$$

Let l be constant for a particular case. Then the strength is constant if $\frac{k^2}{a}$ is constant. If this ratio is variable the strength of the column is variable, for deflection in different directions as controlled by guides near the middle. For each position of the guides there may be noted a deflection, a radius of gyration, and a knife edge component.

According to considerations previously noted, the column is counteracted in its tendency to deflect by a moment Tk at the middle, and Tx, say, at the end; where x is the arm of the moment. Now for the middle cross section of the column; let the radius of gyration be found for a number of different directions within the circumference. Lay these off as in Fig. 25 where OE OG OH OK are 4 values for the 4 respective directions. Then trace the curve EG HKE. Any radius vector to this curve will be the value of k lying in the direction of that radius vector.

The point O represents the axis of the column. Let AB represent the knife edge bearing at one end of the column, its effective length being laid off to the same scale as k. The effective length should be less than the actual length, for the same reason that k is less than d_1; that is, the pin bearing will crush for some distance, corresponding to d_1-k.

Now for a constrained deflection toward OA, lay off x=OA as the moment arm. This added to k gives OK+OA=OL. Again for a constrained deflection toward OJ the knife-edge component of

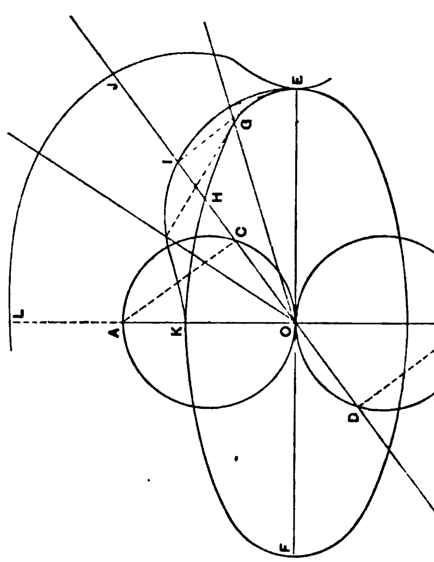

Figure 25.

OA will be OC=OA projected upon OJ. C is a point in a circle OCA giving all components. The curve EGHK should be treated in a similar way for finding the components. For instance project upon OJ by the tangent from the curve EGH giving I one point in the curve EIK. Any radius vector to this curve gives the k component for that direction. Now add OC and OI giving OJ. J is another point in the curve EJL, a radius rector to which represents the resultant moment arm. for the moment counteracting deflection in the direction of radius vector considered.

We should yet add the counteracting effect due to the opposite end of the column. Another curve outside of EJL including the three; the middle and the two ends. Then the minimum radius vector to that curve will be in the direction in which the column will deflect when unconstrained.

In practice it will be found that for almost every possible case, the minimum radius vector will lie in the direction of OA or OE so that the column will but rarely deflect diagonally. The minimum load value of the column will be found by computing for the direction of deflection above indicated. If the deflection takes in the direction of the pins, a is to be found from (111) by ignoring r and taking k_c and k_d as equal the respective values of OA.

If the knife edges be at right angles, the curve, Fig. 25, obtained will be found to have minimum ordinates in the directions of the pins or knife edges.

Fig. 25 applies especially for the long column formula. For shorter columns proper to the formula (101) we will probably find less decided differences between max. and min. radii vectors to Fig. 25 until for short blocks the differences are either indeterminate or indistinguishable.

Open Column Stays.—Open built columns are occasionally deficient in trussing or latticing. For instance, two 8″ channel bars may be joined by $\frac{3}{8}$″ plates 10″ square riveted on in such a way that the plane sides of the bars are back to back with an intervening space of 6 or 7 inches, the flanges being turned outward. Then if the plates are placed 3′ 10″ apart along the bars, the column thus constructed will probably be deficient in cross stays. In such case the column will fail to carry the load determined for it by the usual formula and actual moment of inertia of the cross section. To illustrate, the failure may be as shown in Fig. 26 as indeed experiment

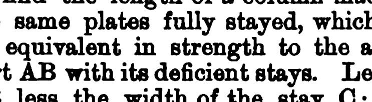

Figure 26.

has given, the parts ABC acting like little columns with fixed ends. It is proposed to find the length of a column made o the same plates fully stayed, which will be equivalent in strength to the actual part AB with its deficient stays. Let l'= AB less the width of the stay C; l''= length of equivalent full-stayed column. Then if the parts AB and DE are regarded as small columns with fixed ends, we have by applying the simple long-column formula for the purpose of securing a simple correction

$$T=4\varepsilon I'\frac{\pi^2}{l'^2}=4\varepsilon I_1\frac{\pi^2}{l''^2}$$

where I′ is the sum obtained by finding the least moment of inertia of each of the parts AB DE &c. taken separately and added; and I_1 the least moment of inertia of the entire section of the column obtained in the usual way as such. In this section, the staying is not counted. There the square of the ratio obtained by dividing the equivalent full-stayed column length by the actual column length supposed insufficiently stayed is obtained by solving the above for l''^2 and dividing by l^2, giving

$$\left(\frac{l''}{l}\right)^2=\frac{I_1}{I'}\left(\frac{l'}{l}\right) \quad . \quad . \quad . \quad (112).$$

This forms a co-efficient for l^2 in any of the column formulas. For instance, if $\frac{I_1}{I'}\left(\frac{l'}{l}\right)^2=3$, then in formulas (97), (98), or (99), &c., l^2 therein, should be multiplied by 3, when (112) is less than 1 it is not to be applied. This fact indicates that the column is sufficiently stayed.

Stay Spacing.—In the last statement we have the suggestion of a formula for determining the spacing in built columns. That is to say, placing the 2d member of (112)=1, and solving for l', we have twice the greatest allowable space between stay points in open-built columns, or,

Greatest admissible space between stay points

$$\frac{l'}{2}=\frac{l}{2}\sqrt{\frac{I'}{I_1}} \quad . \quad . \quad . \quad . \quad (113).$$

Thus, if a column be built of 4 angle bars L $\frac{1}{2}$″×3″, situated as forming the corners of a 12″ square in a column 20′ long, the greatest inter-stay space will be about 16 inches. As an example from actual experiment, column No. 33 of G. Bouscaren's report of experiments to the A. S. C. E. gives the spacing of the open column at 18 inches, and it failed by buckling between the lattices. The spacing, according to the formula (113), should not have exceeded about 14 inches, and hence it should have failed, as observed.

As to the space in open columns of different construction, it is evident that AB=l' is twice the space in Fig. 26, and in the first part of Fig. 27. But in the second part of the latter, AB $=l'$ is to be counted as the space where the cross and diagonal staying together serves to fix the ends of the parts, AB.

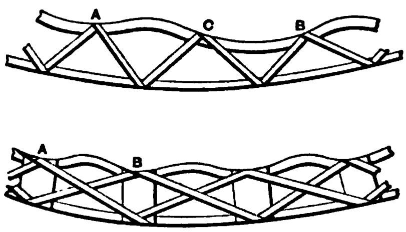

Figure 27.

PRACTICAL FORMULAS FOR COLUMNS.

Collecting the formulas which are useful in practice, we have:

For ordinary columns

$$\frac{T}{K}=\frac{t}{1+\frac{d_1^2}{2k^2}\left(\sqrt{1+\frac{atl^2}{\varepsilon\pi^2 d_1^2}}-1\right)} \quad . \quad . \quad (114).$$

For very long columns,

$$\frac{T}{K}=\frac{4}{a}\varepsilon\pi^2\frac{k^2}{l^2} \quad . \quad . \quad . \quad . \quad (115).$$

Criterion for applying 114 or 115

$$\frac{l}{2d_1}=\left\{\frac{\pi^2}{a\beta}\left(1+\frac{1}{\beta}\right)\frac{\varepsilon}{t}\right\}^{\frac{1}{2}} \quad . \quad . \quad (116).$$

$$\beta=\frac{d_1}{k}$$

For adapting to actual end conditions, see Fig. 23.

For flat ends,

$$a=\frac{4}{\left(1+\frac{k_c\sqrt{K_c}+k_d\sqrt{K_d}}{2d_1\sqrt{K_m}}+f\frac{r_a+r_b}{2k_m}\right)^2} \quad . \quad . \quad . \quad (117).$$

For *fixed* ends change d_1 to k_m

Co-efficient for l^2, in (114) and (115) for columns deficient in staying,

$$\left(\frac{l''}{l}\right)^2=\frac{I_1}{I'}\left(\frac{l'}{l}\right)^2 \quad . \quad . \quad . \quad (118).$$

Inter-stay spaces in open columns

$$\frac{l'}{2}=\frac{l}{2}\sqrt{\frac{I'}{I_1}} \quad . \quad . \quad . \quad . \quad (119).$$

where $l'=$ AB in Figs. 26 and 27.

In these formulas,

T = load borne by the column.

t = compressive resistance per square inch corresponding to T.

K = cross section of column, K_m at middle; K_c and K_d at ends, either when flat or fixed, and when flat to be taken as the flat-end surface. Only for suporting members.

d_1 = distance from the center of gravity of the section K_m to where the strain is t, and measured on the plane of the curve of flexure.

$d = 2d_1$ in symmetrical cross sections, and equal the diameter of the column reckoned parallel to plane of flexure.

k = radius of gyration of the cross section, k_m, least radius at the middle of column; k_c and k_d radii for the end sections for fixed ends; or of the end surface for flat ends, and to include supporting members only.

l = length of the column.

ε = coefficient of elasticity of the material composing the column.

f = coefficient of friction of a column on its pin bearing, = about .25 to .5.

r_a = radius of pin at one end of column.

r_b = radius of pin at the other end of column.

I_1 = least moment of inertia of the entire cross section of supporting members taken in their actual relative position, and exclusive of staying.

I' = aggregate moment of inertia obtained by finding the least moment of inertia of supporting members taken separately, and adding

$\frac{l}{2d_1}>$ than in (116), apply (115).

$\frac{l}{2d_1}<$ than in (116), apply (114).

a = 4 for columns terminated in points or knife edges.

a = 1 for columns terminated in fixed ends no smaller than the middle of column.

a = $\frac{16}{9}$ for columns having one end pointed and one end fixed and large as middle.

a = (117) in other cases.

OTHER FORMULAS.

The well-known formulas of Hodgkinson appear to be the first of substantial value, their constants being wholly empirical. They were applicable to only a few forms of cross section, and entirely inadequate to the present engineering practice.

Lewis Gordon determined the constants for Tredgold's formula from the experiments of Hodgkinson, which, on account of its partly theoretical basis, was found to have a much wider range of applicability than Hodgkinson's formula. It came into quite general use, and was known as Gordon's formula. Rankine has displaced the least diameter, h, in this formula by the least radius of gyration, thus producing the most acceptable formula in use to-day.

The form of this expression is:

$$w=\frac{fK}{1+a\frac{l^2}{k^2}} \quad . \quad . \quad . \quad . \quad (120).$$

where f and a are empirical constants, the former being nearly the ultimate resistance to crushing; K and k, the cross section and its least radius of gyration respectively, at the middle of the column length, l. The values adopted by different engineers for f and of a differ greatly, even for a given material, so that in bridge specifications it is common to see the chosen values of f and a given. Besides this, it is impossible to determine values for f and a for any particular material, except by actual column experiments—a fact which practically limits the formula to a few materials, and even then to a comparatively few experiments. Hence, a general formula whose constants consist of such factors as the coefficient of elasticity, modulus of crushing, &c., seems, by reason of the plentitude of these factors, very desirable.

These facts have caused search for such theoretical formula. One of the first formulas of this kind appears to have been proposed by Reuleaux, and published in *Der Constructeur*, the same being quoted by Ritter in his translation by Sankey of *Bridges and Roofs*, in 1879. See *Sankey's Ritter*, p. 345. The first edition was published in 1862.

This expression for rounded ends is of the form

$$w=\frac{cK}{1+\frac{cKl^2}{8\varepsilon I}}$$

$$=\frac{cK}{1+\frac{c}{8\varepsilon}\frac{l^2}{k^2}} \quad . \quad . \quad . \quad (121).$$

where c = resistance to compression, proposed to be taken within the elastic limit for a safe load, ε the coefficient of elasticity. K l and k as before. The form of (121) is seen to be the same as (120). That is to say, the load for a given material is equal to a constant times the section; divided by 1 + a constant times the square of the ratio of the length to the radius of gyration of cross section

Notwithstanding the agreement in form, (121) has the advantage of applicability to all materials for which C and ε are known, for many of which (120) might not be known. Even if (121) should give discrepancies as it stands, an empirical qualifying coefficient could be found which would probably be nearly the same for one material as another.

An expression of the same form as (121) for round ends was proposed by Mr. J. D. Crehore, and published in VAN NOSTRANDS MAG. for Dec., 1879, under the title, "A New Rational Formula for Pillars." Mr. Crehore's formula however differed in displacing 8 by π^2 in the denominator of (121). To account for this, Reuleaux treated the axis of the deflected column as a circle arc, while Crehore showed it to be a sinusoid. Hence Crehore's formula for rounded ends was

$$w=\frac{CK}{1+\frac{Cl^2}{\pi^2\varepsilon k^2}} \quad . \quad . \quad . \quad (122).$$

An expression identical with this for columns with round ends was given in an article by E. Hatzel, translated for VAN NOSTRAND'S ENG. MAG. for Sept., 1877; except in Hatzel's formula the moment of inertia was taken for an axis at other points in the section than the center of gravity; whence the radius of gyration k would be other than the principal radius.

Also Crehore showed that for flat ends the 2d term of the denominator of (122) should be divided by 4, and for one flat and one rounded end it should be divided by $\frac{16}{9}$.

Crehore's formulas were reproduced in an elaborate article by Professor W.

Baldwin, and published in VAN NOSTRAND'S MAG. for May, 1880, with due credit to Mr. Crehore. But in the same article Professor Baldwin utterly abandons these formulas, and proceeds to the discussion of the Gordon formula containing the least thickness h, and of the Rankine formula containing the least radius of gyration k. Adopting the latter, its constants are determined from a great number of experiments cited, and for a variety of materials. But no attempt was made to generalize by retaining C and ε. The reason given is that ε is not constant in failing material, and at the point of rupture is unknown. This is to be admitted, especially in tension; but in compression the value remains very nearly constant for both cast and wrought iron. This is fortunate, because the chief factor concerned in the strength of columns is the compressive resistance. As the column fails by deflecting to one side, the material is most severely compressed at the concave side, and only a small portion of the cross section will be involved in incipient fracture. Existing results of experiment show that ε is practicably constant for compression of cast and wrought iron to near the failing point, where it drops suddenly from 10 to 20 per cent. Hence if a tenth of the section is effected by 15 per cent. reduction in ε, the resulting effect upon the whole section would be one and one-half per cent., a quantity which may be ignored in calculating the strength of columns. Hence we propose to compare the rational formulas with experiment before giving them up.

But before taking up numerical facts we observe that the Reuleaux, Hatzel, or Crehore formula differ from the rational formula (97) for rounded ends, believed to be given for the first time in this article, in the form of the denominator. To show that this difference is an important one, we have from Fig. 21

$$ab : b\text{B} :: \text{BA} : \rho$$

or

$$ab : d_1 :: 1 : \rho$$

Also ($4\frac{1}{2}$) gives $t_1 = \varepsilon . ab$

$$\therefore \quad \frac{1}{\rho} = \frac{ab}{d_1} = \frac{t_1}{\varepsilon d_1} = y_1 \frac{\pi^2}{l^2}$$

the last expression being found in the first of (95).

whence

$$y_1 = \frac{t_1 l^2}{\varepsilon d_1 \pi^2}$$

in which t_1 is the compressive force which is sufficient to cause the shortening ab and a force which is due to bending only. Combining this with (8) or (96 a) we have

$$t = \frac{\text{T}t_1 l^2}{\varepsilon \text{I}_1 \pi^2} + \frac{\text{T}}{\text{K}}$$

which, solved for T, gives for columns with rounded ends,

$$\text{T} = \frac{t\text{K}}{1 + \frac{t_1 \text{K} l^2}{\pi^2 \varepsilon \text{I}_1}} = \frac{t\text{K}}{1 + \frac{t_1 l_2}{\pi^2 \varepsilon k^2}} \quad . \quad . \quad . \quad (123).$$

an expression identical with Crehore's, except that t_1 is not the compressive resistance; Fig. 21 showing that it is only a part of it. In this expression t is the total compression represented by ad, and hence for rupture the total compression $t = \text{C}$ of Crehore's formula. But t_1, represented by ab, cannot be C, and hence some oversight appears to have been committed in making it C in formula (122). This explains the difference in form between (97) and (122); and gives sufficient cause for a disagreement of one or the other with experimental results.

In the developed denominator of (97) see (102) and (103), we have in the terms, $1+v$, (observing that $a=4$ for rounded ends) the identical denominator of (122). Hence to the remaining terms of the denominator of (103) we may look for the compensating quantity for the error $\text{C}=t_1$. The same fault is common to the Reuleaux, and to the Hatzel formulas though in the former a compensating effect appears to be provided in the values compounded of C and ε for use; and in the latter in assuming the moment of inertia axis at or near the convex side of column.

Direct Comparison.—But the column formula problem is one which cannot be satisfactorily settled for practical men from a purely theoretical standpoint. I therefore offer the following comparison of column formulas. As the numerator may be considered as practically the same in all, the denominators only are compared.

Hence for the denominator we have for the

Gordon formula, $1+a\frac{l^2}{h^2}$

For round ends.	Round and fixed.	Fixed.
$a=\frac{4}{3000}$	$\frac{2}{3000}$	$\frac{1}{3000}$

Rankine formula, $1+b\frac{l^2}{k^2}$

For round ends.	Round and fixed.	Fixed.
$b=\frac{4}{36000}$	$\frac{16}{9}\,\frac{1}{36000}$	$\frac{1}{36000}$

By G. Bouscaren, C.E., and adopted by Keystone Bridge Company.

For round ends.	Round and fixed.	Fixed.
$b=\frac{2}{36000}$	$\frac{3}{2}\,\frac{1}{36000}$	$\frac{1}{36000}$

Reuleaux formula, $1+\frac{Cl^2}{8\varepsilon k^2}$ round ends

Crehore formula, $1+q\frac{Cl^2}{\pi^2\varepsilon k^2}$

For round ends.	Round and fixed.	Fixed.
$q=1$	$\frac{1}{2.28}$	$\frac{1}{4}$

New formula, $1+\frac{d_1^{\,2}}{2k^2}\left(\sqrt{1+\frac{atl^2}{\pi^2\varepsilon d_1^{\,2}}}-1\right)$

For round ends.	Round and fixed.	Fixed.
$a=4$	$\frac{16}{9}$	1

From these expressions for the denominators, I have computed the results found in the following

TABLE OF VALUES OF DENOMINATORS FOR WROUGHT IRON.

Data.	End.	Gordon.	Rankine.	Bouscaren-Keystone.	Crehore.	New.
Solid cylinder.....	Rounded......	5.8	7.4	4.2	9.23	5.20
l=10 ft............	Round and flat.	3.4	3.84	3.4	4.66	3.74
Diam.=2 in.......	Flat.....	2.2	2.6	2.6	3.06	2.50
Bar 2×12 in.......	Rounded......	5.8	5.8	3 4	7.19	4.06
	Round and flat.	3.4	3.13	2.8	3.75	3.06
l=10 ft............	Flat..........	2.2	2.2	2.2	2.54	2.17
Hollow cylinder...	Rounded......	4.00	1.26	1.13	1.33	1.30
Diam. 8 in. and 6 in.	Round and flat.	2.50	1.14	1.10	1.15	1.17
l=10 ft....... ...	Flat..........	1.75	1.06	1.06	1.08	1.08
Hollow Rectangle..	Rounded	3.70	2.49	1.74	2 92	2.16
8×15 in.×6×13 in.	Round and flat.	2.35	1.65	1.56	1.85	1.74
l=30 ft............	Flat..........	1.67	1.37	1.37	1.48	1.39
Means.............		3.231	2.828	2.213	3.353	2.464

For the last two columns $t=C=40000$, $\varepsilon=23370000$, and $\frac{t}{\varepsilon\pi^2}=\frac{1}{7000}$.

The first three formulas named in the table have been in quite general use, and yet the results shown in the table obtained from them differ in some cases nearly four hundred per cent., as for instance for the Gordon formula applied to hollow cylinders.

Results by the Crehore formula run high in value, one-half of all in the table going above those by the first three named formulas. It appears to give better results for hollow than for solid sections. But the large denominator gives small column load so that the formula errs on the safe side.

Results by the new formula are seen in every case but two, to fall between those of the first three "old reliable" formulas, and those two are outside only from one to three per cent. In comparing the means, we see that the new formula falls between the first three. If we reject the Gordon formula, which is now going into disuse in the most approved practice, and compare the new formula with the 2d and 3d columns of results, we find the mean by the new formula falls between the means of the 2d and 3d columns. Indeed it differs but little over two per cent. from the means of the two columns. This appears the more favorable from the fact that the results in the 2d and 3d columns are obtained from formulas which are probably the best in use to-day in the engineering world.

Comparisons have not been made for other materials than wrought iron, for the reason that wrought iron is the chief material in use at present in large trusses where struts are required.

FORMULAS COMPARED WITH EXPERIMENT.

To make the comparison of the new formula with others in such a way as will be yet more satisfactory to practical men, the breaking load of 33 columns of wrought iron, boxed and open built, such as used in bridges, has been computed and placed opposite the breaking load found by actual test in a testing machine. Also in the table is placed the calculated breaking load as found from the Rankine formula, the Bouscaren-Keystone formula, and of the Rankine formula as worked over by Prof. Baldwin for new coefficients, and given in his article above referred to.

In all cases except in Baldwin's formula, the coefficient in the numerator corresponding to the resistance to crushing, was taken at 40,000 lbs. In Baldwin's formula all the coefficients were used as given in the Magazine. The value of ε for the new formula was used, except in a few cases, as given by the experiments, when given. Corrections were made for pin friction, and for excessive stay spacing for two cases. But these probably effect the final result only 2 or 3 per cent., because the number of corrections needed were so few. But the per cent. for the individual cases was sometimes very considerable. The breaking loads stated are per square inch of cross section of column.

The experimental results cited are from a paper by G. Bouscaren to the Am. Soc. Civ. Engrs. on the strength of wrought iron columns. They are stated by some writers to be from Lovet's report, though I find no mention to this effect in the paper to the society.

The columns cited are of five distinct forms of built columns, viz.:

P. "Phoenix," hollow cylinder, four flanged segments riveted.

K. "Keystone," octagonal tube, four flanged segments riveted diametrically.

A. "American," two flanged bars riveted to the flanges of a central I beam.

S. "Square," hollow, two plates and two channel bars riveted with flanges outward.

O. "Open," two channel bars, flanges outward, latticed with slats, riveted trellis-like.

The signs in the last four columns are proper to make the quantities there appearing, correct the computed values of the resistances to agree with the resistances by experiment.

The sums, + and −, appearing at the foot of the first two columns qualified with signs make it appear that the formulas give results which are too large. Hence it appears that the 40,000 used in the numerator of the Rankine and Bouscaren-Keystone formula is too high. It was used in the Rankine formula for convenience, and because it is found in the Keystone formula. But as Rankine gave the formulas the quantity was 36,000, the same as in the Baldwin formula for flat ends, for which also the denominators agree. Hence the quantities by the Baldwin formula down to No. 5 may be regarded as coinciding with Rankine's. The values in Rankine's space from No. 5 down for round ends should be reduced 10 per cent. to change from 40,000 to 36,000. In order to present the results as would be thus given for Rankine's formulas unmodified, or for the numerator at 36,000, they have been worked out and given in the second set at the foot of Rankine's column of differences. The reduction from 40,000 to 36,000 is evidently too great as in one set the — values predominate, while in the other it is with the + values. An estimate made on this score would indicate that 38,000 would be about the best value for the Rankine formulas, the same indeed as is known to be in use by some Ry. Cos. It appears also that 40,000 is too great for the Keystone formula.

In glancing over the four last columns

TABLE OF COMPUTED RESULTS COMPARED WITH EXPERIMENTS.—BUILT WROUGHT IRON COLUMNS.

No. and style.	Length feet.	Breadth inches.	Sec. area sq. in.	k^2	ε Millions.	Resistance per sq. ins. Experiment lbs.	Rankine formula.	Bouscaren-Keystone formula.	Baldwin formula.	New‡ formula.	Difference, Rankine.	Difference, Keystone.	Difference, Baldwin.	Difference, new.
9.K	15	8.85	23.67	7.833	24.7	32000	35900		32300	34500	− 3900.		− 300.	− 2500.
2 "	5	10.1	14.25	11.044	—	33600	39600		35670	39300	− 6000		− 2070	− 5700
25 "	27	12.	18.83	11,424	28.1	21100	31870		28800	30800	− 10770		− 7700	− 9700
24 "	27	9.5	19.20	12 041	26.5	25000	32600		29300	29800	− 7600		− 4300	− 4800
27 "	27	8.62	18.83	9.798	23.7	27800	30800		27700	29800	− 3000		+ 100	− 2000
26 "	27	9.88	14.49	11.178	27.5	27500	31900		28700	29200	− 4400		− 1200	− 1700
30 "	27	9.5	15.13	11.464	19.3	30000	32100		28900	29400	− 2100		+ 1100	+ 600
31 "	27	12.	15.13	11.464	23.6	25400	32000		28800	30900	− 6600		− 3400	− 5500
19.A	27	10.	20.10	13.510	25.0	27800	32900		28900	31800	− 5100		− 1100	− 4000.
10.P	27	8.12	13.70	8.935	19.1	31000	30200		27100	30000	+ 800		+ 3900	+ 1000
29 "	28	8.25	13.58	8.935	28.5	36600	29600		26600	39300	+ 7000		+10000	+ 7300
6 "	15	8.05	14.09	8.536	27.4	37500	36200		32600	35400	+ 1300		+ 4900	+ 2100
28 "	28	8.25	13.58	8.935	25.7	34800	29600		26600	28400	+ 5200		+ 8200	+ 6400
23 S	24	10.	13.70	11.628	28.9	33200	33400		30100	32700	− 200.		+ 3100	− 500
22 "	26	10	13.60	9.347	27.8	30000	31000		27920	30000	− 1000.		+ 2080	± 000
32 "	27	10.5	26.05	10.909	30.1	30200	31600		28400	30500	− 1400		+ 1800	− 300
20.A*	10	8	9.66	10.90	27.6	20000	37400		40600	18600	− 17400		−20600	+ 1400
34.O.*	12.25	9	6.00	18.06	(24.)	17600	38700		34800	18100	− 21100		−17200	− 500
37 "	27.48	14.	12.08	19.98	"	29600	34750		31300	33200	− 5150		− 1700	− 3600
38 "	23.	14.	13.48	20.69	"	32300	36300		32600	34900	− 4000		− 300	− 2600
39 "†	2.	2.8	6.60	0.70	"	35400	39100		35200	38800	− 3700		+ 200	− 3400
40 "†	1.61	2.8	6.60	0.70	"	35700	39100		35200	38700	− 3400		+ 500	− 3000
41 "	27.5	14.	13.74	20.79	"	32400	34960		31400	33600	− 2560		+ 1000	− 1200
42 "	27.5	13.	11.05	21.26	"	32300	32600		29400	30950	− 300		+ 2900	+ 1350
5.K	27.	11.6	13.12	10.945	29.5	22000	19360	26100	19600	20070	+ 2640	− 4100	+ 2400	+ 1930
16.A	20	8.	12.50	5.497	28.9	26700	18500	25200	14760	24000	+ 8200	+ 1500	+11940	+ 2700
13 "	26	12.	25.05	18.215	30.4	24000	25100	30800	17800	26800	− 1100	− 6800	+ 6200	− 2800.
21.S	25.75	10.	13.60	11.000	31.0	25500	20400	27000	20800	25600	+ 5100	− 1500	+ 4700	− 100.
33.O	28.53	10	5.68	20.07	32.4	31700	23200	30300	33600	27600	+ 8500	+ 1400	− 1900	+ 4100
36 "	34.00	10.25	7.48	8.73	(24.)	23130	12800	19400	12310	19800	+ 10330	+ 3730	+10820	+ 3330
11.P	25.19	8.12	13.89	8.935	27.1	21700	18260	25100	18220	20160	+ 3440	− 3400	+ 3480	+ 1540.
17 A	20	10.	19.90	8.733	23.1	26500	23080	29270	24130	25140	+ 3420	− 3770	+ 2370	+ 1360.
14 "	26	10.	20.72	8.733	26.	22000	17870	24800	17900	21300	+ 4130	− 2800	+ 4100	+ 700.

(In the Bouscaren-Keystone formula column:) For the blanks in this space, the columns have flat ends; and the values are the same as for the Rankine formula. Where values are entered below, the columns have pin bearings.

(In the Difference, Keystone column:) For the blanks in this space the values are the same as for the Rankine formula.

	Difference, Rankine.	Difference, Keystone.	Difference, Baldwin.	Difference, new.
Sum of + discrepancies	+ 60060.	+ 20930.	+85790.	+35810
Sum of − discrepancies	−110780	−132050	−61770.	−53900
Mean discrepancy, regardless of sign	5177.	4636.	4471.	2718.
Mean discrepancy, regardless of sign, rejecting Nos. 20 and 34.	4010.	3469.	3326.	2661.
Rankine formula sum of + discrepancies for numerator=36000.	+102310.			
Rankine formula sum of − discrepancies for numerator=36000.	− 59870			
Mean discrepancy, regardless of sign	4915.			
Mean discrepancy, regardless of sign, rejecting Nos. 20 and 34.	3769.			

* Insufficiently stayed or trussed. Correction (118) applied for the new formula † Simply a single piece of channel bar, about 2.8″ ×12″. ‡ For the new formula the flat ends were regarded as fixed because of the enlargement of ends, strengthening by special riveting, &c.

it is seen that in the first the — signs are chiefly among the results for flat ends, while the + signs predominate at the round ends. This indicates that the Rankine formulas are constitutionally at fault, or perhaps that the 1, $\frac{16}{9}$, and 4, coefficients to the last term of the denominator for flat, flat and round, and round, ends differ too much. As adopted in the Bouscaren-Keystone formula, viz.: 1, $\frac{3}{2}$ and 2, the discrepancies would probably be less, as indeed the column footings show. With these coefficients it would appear that a better numerator would be about 38,000.

The column of differences due to the Baldwin formula are found to be far more satisfactory than either of the two preceding it. That is to say, the signs are more generally intermixed, the + and — values sum up more nearly equal to each other numerically, and the average discrepancy, without sign is smaller.

If, however, Nos. 20 and 34 were cut out from the table, the + and — sums would more nearly agree in value for the Rankine formula than for any of the others. But the mean error without sign would be higher than for any of the others, as indicated by the figures given. Though the Baldwin formula still excels the Rankine and Keystone formulas in the smallness of mean error, yet the difference in + and — sums is greater.

But in every respect we find the last column of figures, which are due to the new formula, by far the most favorable. That is to say, the individual discrepancies in that column run lower in value, the number of + and — values are more nearly equal; the absolute values of the sums of the + and — quantities are lower and differ less; and the mean error, or discrepancy, is lowest. This, together with the fact that the theoretical values, 1, $\frac{16}{9}$ and 4 are employed, whereas in other formulas, they seem to differ too much, would indicate that the new formula is more nearly theoretically perfect than any of the others. But, in spite of these advantages, the new formula is, unfortunately, less convenient in application than the others, and the question will doubtless arise in practice, whether or no, for an important structure, to sacrifice the additional hour required for the more trustworthy results by the new formula.

As the present object is formulas for bridges, and as wrought iron is the material chiefly employed, no attempt has been made to compare the new formula with others for other materials than wrought iron. It seems probable, however, that where the coefficient of elasticity, ε, is practically constant nearly to the point of rupture, the formula may be used without hesitation. The point of rupture is here meant to be either for rupture by tension or compression. For such a material as cast iron it may be necessary to be guided partly by empiricism, especially for long columns, where the rupture may take place on the convex side by tension, because, in tension, the ε rapidly falls off in value, as rupture is approached. But in compression, ε is more nearly constant, and hence in short columns the formula will probably apply with greater exactitude.

The great difference in the ultimate resistances to tension and compression in cast iron will also cause an approach to rupture on the convex side, relatively, much sooner than for other materials, so that the rapidly diminishing value of ε will effect much shorter columns than otherwise. For cast iron in particular, therefore, it may be necessary to use a low value of the modulus of compression and of ε, and more so as the length increases, say 60,000 to 80,000 for the former, and 12 to 20 million for the latter.

A rational formula must certainly prove much more satisfactory for a comparatively new material, such as some of the grades of steel, than an entirely empirical formula which has not been adapted, that is, in cases where reliable values of the compressive resistance and of ε are known, and not of the constants in the empirical formulas.

MULTIPLYING EMPIRICAL FORMULAS.

Where numerous results of experiments exist for particular classes of columns, it may be possible to adopt an empirical formula for each class, or part of a class, which shall give the results for such columns, or at least to reproduce the particular values to which those formulas are adapted, with closer agreement than any single or perfectly general formula would do. But this process leads to some degree of confusion in the considerable number of formulas produced, and new experiments may develop need of additional formulas, or require a modification of former ones.

In the above tables, comparisons were made only with formulas which are proposed to be perfectly general. But *Trautwine's Pocketbook* cites six different formulas by D. J. Whittemore, C. E., which, accordingly, would be required in computing strains for three of the forms of columns in the above table, and including only 17 of the experimental tests. Though Whittemore gives 12 different formulas, only 6 apply, and half of the experimental columns cited in the table are left by him without a formula.

In a recent paper by Prof. Wm. H. Burr, ten different formulas are produced from twenty-nine experiments. The experiments are mostly cited in the above table, and the formulas, when the whole ten are used, each for its intended form of column, give results agreeing remarkably well with the experiments. The mean error, regardless of sign, is 1720—a quantity less by about 33 per cent. than the mean by the new formula from all the experimental columns cited in the above table, viz., 2661 (two being left out). But when we observe that in this comparison, the new formula, obtained independently of all experiment or specified material, is arraigned before 10 formulas which were obtained from the very experiments compared with, and at the rate of one formula to three experiments, it does not seem strange that the ten formulas should reduce the mean error. Considering the idiosyncracies of column tests, are we at all confident that n extending the application of the 10 formulas to 30 new tests, the mean error will remain as low as indeed either of the values cited?

FACTOR OF SAFETY IN COLUMNS.

The usual way of providing for safe loads for columns is to take a certain fractional part of the breaking load; say such a fractional part as is taken in eye bars. The fraction $\frac{1}{5}$ is common. Thus, the ultimate resistance of wrought iron to tension is about 50,000 lbs. per square inch, and the $\frac{1}{5}$ part, or 10,000 lbs., is almost an absolute conventionalism among bridge builders, and may be regarded nearly in the sense of an absolute modulus of working resistance to tension.

Accordingly, $\frac{1}{5}$ is prefixed to column formulas (Rankine's and Gordon's) by many bridge engineers, as giving the proper fractional part of the ultimate resistance, which is to serve as the safe working resistance. But in empirical formulas, where the composition of the constants is unknown, this is a blind practice, because, from analogy with eye-bar strains, $\frac{1}{5}$ of the ultimate compressive resistance of the *material* is evidently meant, instead of $\frac{1}{5}$ of the resistance of the *column*.

This matter can be corrected in the Rational formulas, and it will be seen that the "$\frac{1}{5}$" coefficient to the empirical formulas for columns gives an unintentionally small safe load. A glance at formulas (114) and (120) will suffice for this. Thus, (114) shows that by using $\frac{1}{5}$ of the ultimate resistance to compression, t, we effect both the numerator and the second term of the denominator, whereas, in (120), we only modify the numerator by taking $\frac{1}{5}$ of the breaking load by formula.

To indicate how the "safe load" is effected by the empirical as compared with the rational method, the following values have been computed for certain ones of the columns in the principal table above.

	No.	l	$\frac{l}{k}$	For $\frac{1}{5}$ Column breaking load.	For $\frac{1}{5}\,t$ in (114)
Flat end	6	15	5.2	7080	7790
"	23	24	7.1	6540	7680
"	29	28	9.3	.5860	7870
Rounded	16	20	8.5	4800	6320
"	36	34	12.	3960	5325

Here the last column of figures is to be regarded as truly representing the resistance of the columns, per square inch of section, when the maximum strain on the material of the column is only the fifth part of the breaking strain, while the column of figures preceding the last, usually regarded as the fifth part of the breaking load, does not strain the material to more than about one-seventh of its ultimate resistance. But fortunately this difference is on the safe side, so that the majority of existing columns in bridges are amply strong.

The figures in the last column are all less than 8000 lbs., the maximum strain assumed as allowable, that is, the fifth part of 40,000 lbs. The differences are to be considered as provisional, for preventing the strains rising in excess of the 8000 lbs. by buckling or otherwise.

By taking $\frac{1}{7}t$ in place of $\frac{1}{8}t$ for computing the last column of figures, perhaps as close an agreement is obtained with the column preceding it as is possible with a simple fraction. From this fact it appears that the "factor of safety" usually employed for columns has been in the neighborhood of $\frac{1}{7}$, or that the working resistance of iron in columns has been from 5000 to 6000 lbs. per square inch, compression. But as a high value of the working resistance to compression is regarded by some prominent engineers as safer than a like high value for tension, it appears that columns have habitually been made unduly heavy.

SEMI-COLUMNS, WITH PIN ENDS AND COMPRESSION.

Perhaps this term will serve to distinguish pieces which are subject to longitudinal and transverse strains; as in Fig. 2, or in Fig. 28 and following.

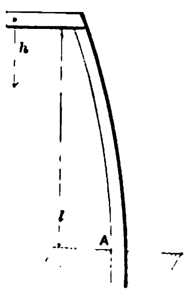

Figure 28.

An expression for the max. strain in the section at A, Fig. 28, is obtained by combining Eq. (8) with (25) and eliminating M. Whence

$$t=\frac{Thd_1}{I\cos nl}\pm\frac{T}{K} \quad . \quad . \quad . \quad . \quad (124).$$

$$\left.\begin{array}{l} \text{where } n^2=\frac{T}{\varepsilon I}=\frac{t'K}{\varepsilon I}=\frac{t'}{\varepsilon k^2} \\ \text{also } \frac{T}{K}=t', \text{and } \frac{T}{I}=\frac{t'}{k^2} \end{array}\right\} \quad . \quad . \quad . \quad (124a).$$

These quantities may, indeed, be introduced with probable greater convenience for application, giving

$$\frac{t}{t'}=\frac{hd_1}{k^2\cos\frac{l}{k}\sqrt{\frac{t'}{\varepsilon}}}\pm1 \quad . \quad . \quad (125).$$

the + sign being used to obtain the max. compressive strain, and the — sign for the max. tensile strain. The piece will fail from the first or second, as depending on the nearest approach of that strain to the modulus of crushing or of rupture. For wrought iron the + sign should be used, while for cast iron, except when h and l are very short, the — sign. The max. strain per square inch is t, tension or compression as just indicated, while t' is the actual average compressive force which is applied to the semi-column per square inch of the cross section. For instance, if the section be 10 square inches and the compressive force applied be 100,000 lbs., $t=$ 10,000 lbs. But the max. t' resulting strain in the semi-column may be $t=30,000$ lbs. per square inch. Also h is the distance from the center of gravity of the end cross section to where the compressive load is applied; d_1 the distance from the center of gravity of the middle section to the side, concave or convex, where the strain t is reckoned; k the radius of gyration of cross section; l the length of semi column, and ε the coefficient of elasticity.

When d_1 is taken on the convex side, and the 1st term 2d member = 1, we will have tension $t=o$.

Though a direct determination of t is effected for an assumed value of t', yet the converse will doubtless most frequently be desired, but cannot be obtained by a direct simple solution. A few trial values of t' however will give a sufficiently close value for t.

For a case like Fig. 29 it is only necessary to put $\frac{l}{2}$ instead of l in (125); whence, for AB$=l$, AC$=h$, and for pin bearings at C and D,

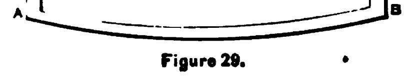

Figure 29.

$$\frac{t}{t'}=\frac{hd_1}{k^2\cos\frac{l}{2k}\sqrt{\frac{t'}{\varepsilon}}}\pm1 \quad . \quad . \quad (126).$$

If there be a load, P, at the middle of the semi-column, acting transversely and downward in Fig. 29, a suitable expression is obtained by substituting M from (23) in (8), observing that for (23), l and P should be changed to $\frac{l}{2}$ and $\frac{P}{2}$ and that the essential sign of M is —.

Hence, for pin bearings, and a load P at the middle

$$t=\frac{d_1}{I}\left(\frac{P}{2n}\text{tang } n\frac{l}{2}+\frac{Th}{\cos n\frac{l}{2}}\right)\pm\frac{T}{K} \quad .\ .\ (127).$$

in which I = the principal moment of inertia of the cross section K, T the whole compressive force applied, and n as given above. P is — for acting upward.

In order that the flexural moment at the middle of the semi-column be zero, the parenthesis should be zero. Whence

$$h=-\frac{P}{2nT}\sin n\frac{l}{2} \quad .\ .\ .\ (128).$$

This value of h is expected to be negative, and it implies that when P acts downward in Fig. 29, the arms h=BD=AC must be laid off downward.

This equation is applicable to upper chords of deck bridges which carry a floorbeam at the middle of each panel, and for determining the position of the pin bearing such that the max. load shall only cause compressive strain in the middle of the panel length. The chord should however be considerably heavier than as thus determined.

By making $h=o$ in (127), we obtain the expression for a column with pin bearings against the middle of which there exists the lateral thrust P, viz.:

$$t=\frac{Pd_1}{2nI}\text{tang } d\frac{l}{2}\pm\frac{T}{K} \quad .\ .\ .\ (129).$$

In deck bridges where numerous floor beams rest on each panel length of the upper chord, as is sometimes the case with wooden floor beams on iron trusses, we have each panel length serving like a column under cross loading, the latter being nearly uniformly distributed.

An expression for such a case is obtained from (35) and (8). Hence for pin bearings

$$t=\frac{wd_1}{n^2I}\text{tang } n\frac{l}{4}\text{tang } n\frac{l}{2}\pm\frac{T}{K} \quad .\ .\ (130).$$

$$=\frac{wd_1}{n^2I}\left(\sec\ n\frac{l}{2}-1\right)\pm\frac{T}{K}$$

where w is the loading per unit length.

With Fixed Ends and Compression.—Where the semi-column is fixed at the ends, as in continuous upper chords, combine (77) with (8) for a load P at the middle; whence

$$t=\frac{Pd_1}{2nI}\text{tang } n\frac{l}{4}\pm\frac{T}{K} \quad .\ .\ .\ (131).$$

which gives the strain at either the middle or end of the panel length.

For a uniformly distributed load, w, for unit length, and for continuous upper chords, we have by (78) and (8)

$$t=\frac{wd_1}{n^2I}\left(1-n\frac{l}{2}\cot n\frac{l}{2}\right)\pm\frac{T}{K} \quad .\ .\ .\ (132).$$

for the end of the panel length, and where the strain t is greatest.

At the middle we will have from $x=\frac{l}{2}$ in (75) and (8)

$$t=\frac{wd_1}{n^2I}\left\{\frac{n\frac{l}{2}}{\sin n\frac{l}{2}}-1\right\}\pm\frac{T}{K} \quad .\ .\ .\ (133).$$

These formulas for distributed loads apply to account for the strain due to the weight of the parts, themselves, as in upper chords of through bridges; and the inclined end posts. In the latter however gravity acts with a transverse component only, which is considerably less than where the piece is horizontal.

Other cases, such as for one pin bearing and one fixed end, is provided for in (63), (64), (65) and (8), two floor beams and pin bearings in (49), &c., &c.

Pin Bearings and Tension.—In lower

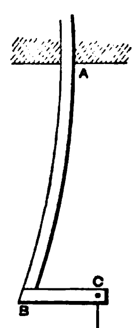

Figure 30.

where the longitudinal force is tension, chords of bridges and other cases we may combine (20) with (8), and obtain an expression adapted to Fig. 30. viz.:

$$t=\frac{d_1}{I}\cdot\frac{2Th}{e^{nl}+e^{-nl}}\pm\frac{T}{K}\quad . \quad . \quad . \quad . \quad (134),$$

where l=AB, and h=BC. Here d_1 will usually be measured on the convex side of beam, and where the + sign will generally be required. Also t will probably always be tension.

The formula for Fig. 31, will be obtained by replacing l in (134) by $\frac{l}{2}$, giving for pin bearings at C and D,

$$t=\frac{d_1}{I}\cdot\frac{2Th}{e^{n\frac{l}{2}}+e^{-n\frac{l}{2}}}\pm\frac{T}{K}\quad . \quad . \quad . \quad . \quad (135).$$

in which l=AB, and h=AD.=BC.

Figure 31.

When a load is applied at the middle, acting downward, we have, by aid of (19) and (8), observing that P in (19) is the half of P here,

$$t=\frac{\frac{Pd_1}{2nI}\left(e^{n\frac{l}{2}}-e^{-n\frac{l}{2}}\right)-2Th}{e^{n\frac{l}{2}}+e^{-n\frac{l}{2}}}\pm\frac{T}{K}\quad . \quad . \quad (136).$$

In order that the flexural moment at the middle of the beam shall be zero, the 1st term, 2d member, should be zero, which condition determines h.

Also h may be zero for a link or eye bar.

For a uniformly distributed load of w per unit length, we have for pin bearings

$$t=\frac{wd_1}{n^2I}\left\{1-\frac{2}{e^{n\frac{l}{2}}+e^{-n\frac{l}{2}}}\right\}\pm\frac{T}{K}\quad . \quad . \quad (137 .$$

Fixed Ends and Tension.—For fixed ends we may combine (72) and (8) for a load at the middle, and for a distributed load (73); and these give strains at the end of the panel length. For the middle employ (74).

Other cases may readily be provided for. For instance, for two floor beams to the panel length, the same resting on the lower chord, use (43) for ends in pin bearings.

For one pin bearing and one fixed end we have (68) and (69), &c., &c. The value of M found from any of these equations may be introduced in eq. (8) to the end of obtaining the maximum strain t, either tension or compression. Equivalents expressed in (124a) are applicable in all.

Examples of Strains in Semi-Columns.—The following examples have been worked to indicate the use of the formulas.

Take a wrought iron end post, or a panel length of an upper chord, length 20 feet, constructed as shown in Fig. 32,

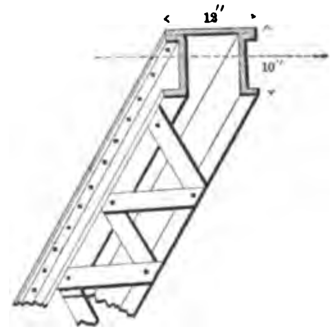

Figure 32.

of two 10'' channel bars of ½''×2½'' flanges × ⅜'' web; a plate 12''×⅜'', and slats, all riveted together as shown. At the ends, proper thickening pieces, gussets, &c., are supposed in use.

Results for the section, with moment of inertia as dotted, are exclusive of latticing,

K=section=12.875 sq. in.
I=205, axis 3'' from plate.
k^2=15.93 in.=radius of gyration.
d_1=3.36 in. plate side.
" =7. " opposite side.
w=wt. per inch length 3.6 lbs.

As a vertical column with knife bearings or pins without friction at center of gravity of sec. and with a max. strain of 10,000 lbs. per square inch, the resistance by new formula = 9011 lbs. for each inch of section.

As a horizontal column with latticing downward, knife bearings, &c., its weight, causes an additional strain of 459 lbs. per square inch, as per first member of eq. (130). This is to be added to $\frac{T}{K}$ = either the 10,000 or 9,011 lbs., according to whether the former or latter is to be regarded as the strain per square inch without flexure. The difference between these figures is the provisional excess mentioned under "factors of safety," and is peculiar to columns. This excess should grow rapidly less as we change from partially indifferent column like strains to positive moments, such as provided for in eqs. (124) and (126).

The strain computed from the ordinary formula for a beam supported at its ends, its weight being the load, and T=*o*, is 404. lbs., a quantity less than the above, as it should be.

We observe that the strain due to the uniform load *w* is, by eq. (130) directly proportional to *w* when T is constant, so that if this load be increased to 40 lbs. per inch or 480 lbs. per ft., the strain will be increased to 5,559 lbs. per sq. in., while by the ordinary formula, ignoring T, it is 4,894 lbs. As an end post inclined at 60° with the horizon the strains will be reduced by a half.

Next, let the loading be P at the middle, of 1,000 lbs., with T and other data as before. As a column in pin bearings, Eq. (127), with $h=o$, gives for the strain due to P 1,090. lbs. per sq. in. By the ordinary formula it is 985.

Transferring the pins to the top of end sections, other conditions as in the last, then h=3.36 in. in (127), and the strain due to 1st term of 2d member of (127) is 1090+578=1668.

To find where to place the pins so that the moment of strain and the middle shall be zero, we have from (128) h= −6.34 inches, which is within ⅜ of an inch of the bottom.

As a last example, let the aggregate section of an iron lower chord be 4″ breadth by 5 inches depth. Let the ends be fixed, as when continuous and clamped at the panel points. Let the panel length carry two floor beams, each with center 18″ from panel point. Suppose the severest strain be due to the drive wheels, and when one pair rests directly on one of the floor beams. Then the other wheels will probably not rest on the other floor beam for unequal spacing. To simplify the work, find the effective load on the floor beam directly under the pair of drive wheels, and let it amount to 23,560 lbs.=Q. Also take the point of contrary flexure near the other floor beam as a point of support. This places the chord in the condition of a beam fixed at one end, supported at the other, and having a load applied at 18″ from the fixed end. Take the beam thus conditioned at l= 129.6″ and let T = 88,000 lbs., ε = 24,000,000. Then,

$$\frac{T}{\varepsilon I} = .000088 = n^2 \qquad n = .009381$$

$$nl = 1.2158 \qquad na = 0.16886$$

$$n(l-a) = 1.0469$$

$$e^{nl} = 3.3729 \qquad e^{-nl} = .2965$$

$$e^{na} = 1.1839 \qquad e^{-na} = .8446$$

$$e^{n(l-a)} = 2.8489 \qquad e^{-n(l-a)} = .3510$$

Then by (69)

$$\frac{P}{Q} = .02968$$

The maximum strain is at the fixed end, where x and $y=o$. Hence, the first member of 68, by aid of P from above, gives

$$M = Qa - Pl = 14.153\ Q = 333500.$$

$$\text{also} \frac{T}{K} = \frac{88000}{20} = 4400,$$

These in eq. 8 give the max. strain per square inch desired,

$$t = \frac{2.5}{41.67} 333500 + 4400 = 24405.\ \text{lbs.}$$

The ordinary formulas for the same case and data, computing the parts separately and adding give

$$t = 24800.\ \text{lbs.}$$

On a Case of Permanent Polarity in Steel opposed to that of the Magnetizing Coil.—By A. Righi.—As a result of his experiments, based on theoretical considerations, the author finds that, "If we take cylindric bars of steel of the same diameter, we always find, for the same value of the magnetizing force of the coil, a bar of such length that it cannot acquire any trace of permanent magnetism; so that with shorter bars we may obtain a permanent polarity contrary to that which is developed during the passage of the current in the coil."—*Il Nuovo Cimento.*

ON THE MECHANICAL PRODUCTION OF ELECTRIC CURRENTS.

From "Engineering."

II.

We have explained how by expending mechanical power in moving a coil of wire past the pole of a magnet, or by moving the pole of a magnet past a coil of wire, we can produce momentary currents of electricity in the coil. We have insisted upon explaining this action by observing the lines of force in the surrounding space, and laid down the rule that the strength of the current so induced in the circuit was proportional to the rate of decrease in the number of lines of force that cross through the circuit.

It will have been observed that in all these actions it is the *relative motion* of magnet and coil that is concerned. It matters not whether the magnet move towards the coil or the coil towards the magnet, the result is the same, an increase in the lines of force threading through the coils, a decrease in the potential energy of the system, and the production of a momentary inverse current. In the actual construction, however, of almost every kind of dynamo-electric machine, the magnets are fixed while the coils move. This is merely for the sufficient reason that the coils are usually lighter than the magnets, and therefore it would be absurd from an engineering point of view to make the moving parts heavier than the fixed parts. In the generators of Pacinotti, Gramme, Wilde, Siemens, Brush, and Edison, the magnets are fixed while the coils rotate. In Lontin's dividing machine and in a few other generators, however, there is an exception. The magnets attached to a central axis revolve, while the numerous coils in which it is desired to generate currents are fixed upon an external frame.

The next step in explaining how the production of continuous currents in one direction is accomplished, in a typical generator, will be a consideration of the effect of moving a ring of wire up to a magnet and passing it over its poles.

In Fig. 13 is shown a single ring or coil of wire to serve as a circuit, and beyond it a magnet is shown with its north pole facing the ring. From what has been already laid down it is easy to say what will be the result of moving the ring along towards the magnet. While the ring approaches the north pole, as in the first case of the figure, the lines of force

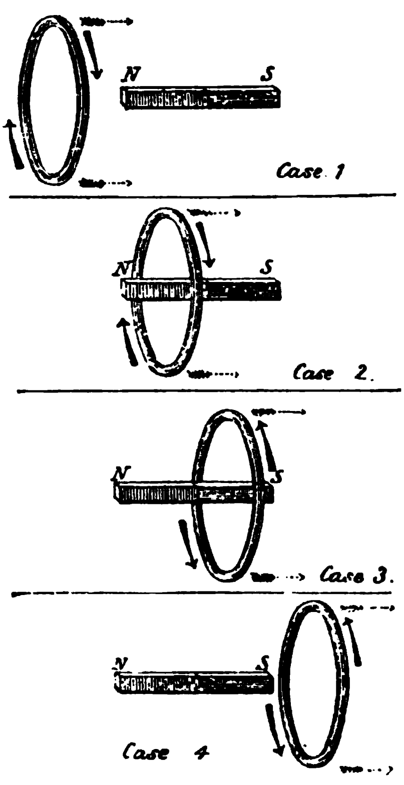

Fig. 13.

that thread through the ring will be increasing in number, and there will be an *inverse* current (*i.e.*, one which is in a direction inverse to that which would cause the pole N to be attracted: compare the figure of case 1 with Fig. 10, and note the direction of the arrows). Moreover, even after the ring has been moved as far as the pole N there will still be an inverse current so long as the ring by moving forward is increasing the number of lines of force that it embraces. Comparison with Fig. 2 and Fig. 11 will show that there will be an increase in the number of lines of force until the ring has got as far as the center or neutral line of the magnet. The second figure of Fig. 13 represents matters up to that point. But now if the forward motion of the ring be continued towards the pole S and beyond it, the number of lines of force that thread themselves through the ring will diminish, and therefore from the moment that it passes the middle point of the magnet a direct current will be induced in it, as shown by the arrows in cases 3 and 4, and these will continue as long as the ring recedes from S.

Again, suppose we move our ring or coil between the two powerful magnetic poles, as indicated in Fig. 14. We will

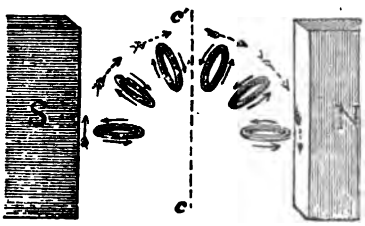

Fig. 14.

suppose that our coil is moving in a circular path between the poles S and N, which are respectively a south and a north pole. The lines of force will run across in almost straight lines from N to S. We will consider what occurs in the coil as it moves round the upper half of the circular path, its first position being on the left. At first it lies horizontal with its plane very nearly along the lines of force, so that almost none of them pass through it. As it rises and turns round the number of lines of force that thread through, the coil increases until it arrives at c', where the number that pass through is a maximum. All this time an inverse current will, therefore, be generated in it. After passing c', and although it is getting nearer N, the number of lines of force that cross through the coil are decreasing, because it is gradually turning round flatways again. From c' onwards there will, therefore, be a direct current induced in the coil. Nor does the direct current cease when the coil arrives at the point nearest N, for now, though not shown in Fig. 14, as the coil goes along the lower semicircle the lines of force will begin again to thread through it, but this time they enter the other side of the coil to that which they formerly entered. There will, therefore, be an increase in the number of lines of force applied negatively, which is, of course, equivalent to a still further decrease. This will go on until the coil arrives at c, where the negative increase is a maximum. All the way round the right hand half of the figure, from c' to c, there will be a direct current induced in the coil. From c onward and round the left hand half of the figure up to c' there will be an inverse current generated. To render such a current available, therefore, as a continuous supply, some device is needed to turn the inverse currents on the left-hand half so that they shall flow into the wires—that go, say, to feed an electric light—in the reverse way to that in which the direct currents flow into them. For if we *invert* that which is already *inverse* we thereby bring it into the *direct* relation. The device for accomplishing this end is called a *commutator*, and the line c c' which marks out the boundary between the currents that are direct and those that are inverse, is known as the "diameter of commutation."

Fig. 15 is a skeleton diagram of the working parts of a Gramme dynamo-electric generator; it is drawn from a model devised by Professor Silvanus Thompson, of Bristol. The well-known ring armature employed in all the machines of Gramme, as well as in the earlier generator of Pacinotti, and the later machines of Schuckert, Brush, and Burgin, is the principal feature. It rotates between the poles S and N of an electro-magnet of a U form with vertical limbs. The commutator consists of a number of separate bars or strips of copper fixed round the periphery of the axis, while above and below are the contact brushes which touch the uppermost and lowermost pieces of the commutator respectively. In the model the ring is enwrapped by a continnous helix of twelve turns; each one of these twelve turns being connected with one of the twelve copper strips of the commutator. In the drawing the armature is supposed to rotate in the same direction as the hands of a clock. The separate turns or coils in the upper half of the ring armature are therefore moving from S towards N, while those of the lower half are moving from N towards S. As in Fig. 14. so here, there will be direct currents generated in all the coils that are on the right hand of the diameter of commutation, c c', and inverse currents in all the coils on the left. The little arrows show the directions of these currents. By following out the various turns of the spiral it will be seen that all the separate currents induced in the individual turns of the spiral on the left of c c' are in the same direction along the wire, and therefore all help one another in producing a strong current, though the electromotive force in each may not be equal. A row of horses hitched on to one another in tandem fashion, facing one way, all help to produce one strong pull, though the individual horses may not be equally strong. In these coils the strongest induced electromotive force is, as a matter of fact, in the coils that are passing closest to the poles. In the right-hand half of the spiral the individual currents are all flowing in the other direction. Up each side of the ring armature, therefore, there is a strong current flowing, drawing electricity from the lowest point and urging it towards the topmost point. Now the bars of the commutator, which are here seen end-on in a ring surrounding the axis, are all separate and insulated from one another and from the axis. If electricity were to flow into one of them it would have to flow back again, for there is nowhere for it to flow to; the bars of the commutator lead nowhere. This is, however, not the case for the two bars of the commutator that occupy the highest and lowest points. They touch against the contact brushes which communicate with wires of the external circuit. So the electricity that flows up both right and left of the ring armature can flow into the upper contact brush and thence into the leading wire of the circuit, which therefore has a constant current urged through it. A corresponding action goes on at the lower contact brush; from this point electricity is drawn both to the right and to the left, being supplied by the return wire of the circuit. The current thus furnished is practically continuous; for though the contact is made first against one bar of the commutator and then against another as fast as they arrive at the line c c', it is clear that the currents on the two sides of the ring armature will always be flowing towards that point at which the contact is made. Neither is there any breach in the continuity of the current generated, because one bar of the commutator does not cease to touch the brushes until the next has come up to contact, and because there always are a certain number of turns of the spiral both on the right and on the left in which the elementary currents are being induced. In the actual dynamo-electric generators the coils of the armatures are of course made up of many turns of wire. In the common Gramme ring, for example, there are hundreds or thousands of turns, and these are grouped in twenty-four sections, the wire at the end of each section being joined to the wire at the beginning of the next, and the junction connected directly with one of the twenty-four bars of the commutator.*

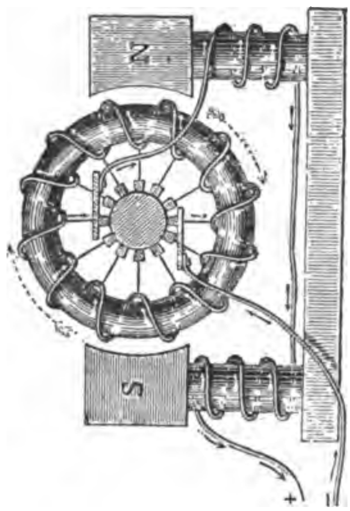

Fig. 15.

Up to this point nothing has been said specifically about the best way of making the magnet poles S and N as powerful as

* The reader, of course, knows that there are other armatures besides the ring armatures of the Pacinotti, Gramme, and Brush machines; there are, for example, the drum armatures of the Siemens machines of modern type, and of Edison's generators. The traction can be argued out in the same manner, however.

possible. All our later arguments simply treated N as the north pole and S as the south pole of a strong magnet. And in the earliest machines for producing currents thus by the mechanical movement of coils in the presence of magnets, the magnets used to produce the requisite "field" of force were ordinary magnets of hard steel. Hence the name of "magneto-electric machines" assigned to the older instruments invented by Pixii, Saxton, Holmes, Nollet, and Siemens. Hence also arose the name "magneto-electricity" for the currents produced by induction in these machines; for it was at first thought by some that the electric currents that were generated in these older machines, and which consisted of rapidly alternating currents, were due to some kind of electricity other than that which flowed smoothly and continuously out of a voltaic battery. But we know now that electricity, whether the source be frictional, voltaic, magnetic, or thermal, is all the same. The term magneto-electricity is therefore happily dropping out of use. A little later, machines were made in which permanent steel magnets were replaced by electro-magnets. Generators on this principle were constructed by Wilde and by Ladd. A small magneto-electric machine with steel magnets furnished a current which was used to excite the field magnet of a large machine. Then followed the famous quadruple independent discovery of Hjorth, Varley, Siemens, and Wheatstone, that there was no need of a separate exciting machine, but that the generator might serve as its own exciter. Suppose the magnet whose poles are S N, to be *very weak*, the currents induced in the coils of the rotating armature will also be very weak. But lead them round the magnet in a spiral, and they will exalt its magnetism, and if it become more powerful it will react on the coils and induce more powerful currents. So, without any permanent steel magnet to begin with, with only masses of iron rendered (as all masses of iron on the earth are) feebly magnetic by the action of the magnetism of the earth, this "action and reaction" principle serves, when the armature is set rotating, to raise the field magnets in a few instants to the highest degree of magnetization which they are capable of acquiring. The model (Fig. 15) shows this, for the wire attached to the upper brush into which the currents generated in the armature are continually flowing is wound round the upright limb of the soft iron field magnet on the right in a spiral, and then crosses to the left, and forms another spiral round the other limb before it passes out to convey the current into the leading wire of the circuit. Such a machine differs only from a magneto electric machine in the particular, that it uses its own current to magnetize its own magnets; and for the sake of distinction machines of this kind have been called *dynamo-electric machines*. But the fact is that all generators, whether they thus supply themselves with magnetism or not, are as truly magneto-electric in their action as if they worked with magnets of permanent steel; for, as we have seen, there must be in all of them a *field of magnetic lines of force* in which the coils move. All the generators are in this sense "magneto-electric." Moreover, in all these generators the energy of the currents is supplied by the mechanical energy expended in producing rotation of the armature. It is not the magnets that supply the constant flow of power. If of steel they are just as powerful at the end as at the beginning. If they are of iron they are no weaker at the beginning than at the end. It is harder work to push the coils across the magnetic field when there is the current flowing in them than would be the case if there were no current, and this extra work the steam engine has to do. The work so done is not, however, lost, as is the work done in overcoming friction; it reappears as the energy of the currents of electricity thereby generated. The *mechanical power* of the steam engine is the real source of the electric power, and therefore all the generators, whether their magnets be soft iron or hard steel, are in this sense "dynamo electric."

In concluding this section let us recapitulate the various points in our argument concerning the mechanical production of electric currents.

Firstly. Magnetic forces must be studied as they exist in the magnetic field or space surrounding the magnet.

Secondly. A wire that carries a current also possesses a magnetic field in the space surrounding it, and the stronger a current is the stronger will be its field, and the more numerous the lines of force that thread through the circle.

Thirdly. If you alter the strength of the field of a current that flows in a wire by moving a magnet pole in that field, you alter the strength of the current in the wire.

Fourthly. If there be no current in the wire to begin with, and you move a magnet near the wire (thereby altering the number of lines of force in the field round the wire), the motion of the magnet will evoke a current in the wire.

Fifthly. Increasing the number of magnetic lines of force that cross a circuit induces in that circuit a transient inverse current; while decreasing the number of magnetic lines of force that cross the circuit induces in that circuit a transient direct current.

Sixthly. When coils of wire rotate across the lines of force of a magnetic field the currents induced in the coils during half their journey are direct; during the other half inverse.

Seventhly. By using a suitable commutator all the currents, direct and inverse, can be turned into the same direction in the wire that goes to supply the currents of the external circuit.

Eighthly. The current of the generator may be utilized to magnetize its own magnets by being made to flow round them in spiral coils, thereby magnetizing them far more powerfully than any permanent steel magnet can be magnetized.

Ninthly. In every case the energy of the electric currents generated is supplied by the mechanical power employed to drive the generator.

To sum up the matter still more briefly we will add a few words. An electric current flowing in a circuit of wire may be regarded as a magnetic whirl in the space surrounding the wire. If then by moving the coil of wire past a magnet we set up magnetic whirls in the space surrounding the coil we set up electric currents in the wires themselves. Dynamo-electric generators are machines for moving coils of wires past the poles of magnets, there being special arrangements, *firstly*, to procure the setting up of very powerful magnet whirls around the coils of wire, and therefore of very strong electric currents in the wires themselves; and, *secondly*, to turn all these currents into one direction so as to flow in one steady stream through the circuit.

A general theory of the action of dynamo-electric generators for the production of electric currents by mechanical power has been developed in the preceding pages. In these articles we have endeavored to fulfill our promise to explain "how electric currents can be produced mechanically, and how magnetism comes in the process." It remains for us to redeem our further promise to explain the relation of electric currents to the work they can do, and to the energy expended in their production.

We laid down as a fundamental principle that to do work of any kind, whether mechanical or electrical, requires the expenditure of an equivalent amount of energy. And that just as a steam engine cannot work without using fuel, or a laborer without food, so an electric current cannot go on flowing, nor an electric light keep on shedding forth its beams without a supply of energy from somewhere or other.

Now, although, as already explained, we use magnets in order to generate currents of electricity in rotating coils of wire, a magnet is not in itself a source of power. It will do no work for us until we have done an equal amount of work on it. We must pull its keeper away from it before it can pull the keeper back and do work. It is just the same with other forces. An iron weight is not in itself a source of power. It will do no work for us—it will not even drive a clock—until we do some work on it. We must lift it (and spend our energy in the process) from the ground, working our muscles to overcome the pull of gravity before it can do the work of driving the wheels of the clock in its descent. In generating electric currents from magnets in the manner explained in the preceding articles, we, or our steam engines, have to supply the necessary energy. We spend this energy in moving something in opposition to a resisting force. This something happens to be a coil of wire, or a combination of such coils. The force happens in this case to be a magnetic force, and the result of the motion happens to be (by the particular arrangements of the coils and magnets) the setting up of magnetic whirls round the wire, or what we otherwise call an electric current in the wire. But it is we (or our steam engines) that do the work. Take a parallel case in mechanics. House bells are often arranged so that when you pull the bell against a resisting spring which when you leave go flies back and rings the bell. Now here the spring possesses a certain power called elasticity, and were it not for this it would not fly back and ring the bell. But the elasticity does not of itself do anything. The spring is not in itself a source of power. It is only when we do work in overcoming its resisting force that it reacts or does work for us; and all the time it is we who supply the energy.

Again, an electric current while it lasts represents a certain amount of active energy. A heavy railway truck shunted along a railway line by the push of a powerful engine represents, while it moves, a certain amount of active energy, for if it crashed against a wall it might knock it down. But presently friction brings it to rest. The electric current also comes rapidly to rest if left to itself, being stopped in the fraction of a second by the resistance it meets with in the metal wire through which it flows. To keep the truck speeding on mile after mile requires a continuous expenditure of energy in the generator.

This brings us back to the whole question of the mechanical production of electric currents in the dynamo-electric machine, and to the point how the mechanical energy of a rotating axis (derived from burning coal in a steam engine) gets converted into the electrical energy of a current flowing invisibly along a wire, which seemingly is quite a different sort of power.

We must again point out that the energy of a current is to be conceived as existing in the space *outside* the wire, quite as much as in the wire itself; that the current itself is always accompanied by magnetic whirls in the space round the wire, and that if we can only set up and maintain magnetic whirls in the space surrounding the wire we set up and maintain currents in the wire itself. Now the way to set up magnetic whirls is to move magnets. And as we cannot set up or maintain magnetic whirls without expending energy, it is clear that we shall have to spend energy in moving the magnets.

Let us go back a little way in our study, far enough to take up again the case of the action of an electric current on a magnet. If we go back to Fig. 10 on page 101 it will be remembered that this diagram illustrated the very important experimental fact that where a magnet and an electric current flowing in a circuit act on one another they tend to move so that the number of lines of force that thread through the circuit, increases to a maximum.

Now the lines of force of a magnet have a definite direction of their own, and the positive direction along them is that in which a free north pole would be urged. A free south pole would be urged, of course, in the opposite direction along the lines of force. The action of our simple voltaic circuit (see Figs. 9 and 10) upon a free north pole would be to suck it in from behind, and to drive it right through the circuit, as the arrows show, along the lines of force to an infinite distance in front. The action upon a free south pole would be just the reverse; it would be sucked in from the front and driven out behind. If we began with a single free north pole at an indefinitely great distance behind the circuit it would be gradually drawn up, and more and more of its radiating lines of force would be drawn into the embrace of the circuit. Imagine yourself looking towards the circuit from the point of space occupied by this ideal magnet pole; as the magnet pole is drawn up nearer and nearer you see the circuit subtending an ever-increasing space in the horizon of your vision, just as a sixpenny piece stuck against a window pane covers up more and more of the landscape as you bring your eye nearer and nearer to it. Think of the circuit as the base of a cone having the magnet pole at its apex. As the pole is drawn nearer the apex grows blunter; its solid angle is ever increasing. Now it can be shown mathematically that the *work* done by the circuit in drawing up the pole in this way from an indefinitely great distance is proportional to the solid angle thus subtended by the circuit. This rule is as important in its way as is the rule that the force with which the circuit draws the pole is proportional to the number of lines of force that are drawn into the embrace of the circuit.

We must now apply one of the first

principles of dynamics to the case. *Potential energy always tends to run down to a minimum.* Suppose we have done work by winding up a spring, or by lifting a weight to the top of an inclined plane, or by pulling away from a magnet the iron keeper that was attached to it. In each case the work done is *stored up* as "potential energy": and in each case there is a tendency for the energy so stored to run down. Our spring will uncoil itself; our heavy weight will descend; our magnet will forcibly draw the keeper back; and each of these actions will result in the work of producing motion. To pull our magnet pole back out of the circuit to which it is attracted will require an expenditure of work; it will pull back like a spring; but when we leave go its potential energy will tend to run down and it will be drawn up again into the circuit.

It is clear then that by pushing the magnet pole up towards the circuit we diminish the mutual energy of the system, while pulling the magnet pole back from the circuit or coil of wire we increase the mutual energy of the system.

But now arises the question; in what part of the system is it that the energy is thus increased or diminished? Is it in the magnet pole, or in the circuit, or in the space between them? The magnet pole is certainly not the seat of the change, for its strength remains the same in all the operations. The change of energy must therefore be either in the strength of the current or in the strength of the "field" of magnetic force that surrounds it. And as you cannot change one without changing the other, we conclude that both are affected.

The application of this very simple principle leads us therefore inevitably to the conclusion that when we push the pole up nearer to the circuit (and diminish the potential energy of the system) this very action diminishes—so long as it lasts—the strength of the current in the wire coil that forms the circuit; and that on the other hand when we pull back the magnet pole out of the circuit (and increase the potential energy of the system) we thereby increase for the time the strength of the current in the circuit.

And if the original current flowing round the coil were *nil?* What then? The argument still holds good, but with this important difference. Seeing that the lines of force of the magnet are the only ones originally belonging to the system, the only way in which they can increase is by a current starting in the circuit, and the only way they can diminish is by a counter current starting in the circuit. This is precisely the result which experiment proves to take place. For, as shown in a previous article, when a magnet pole is pushed up into a coil, it produces a momentary inverse current, and when it is drawn away it produces a momentary direct current in the coil.

To produce powerful currents by a dynamo-electric generator it would therefore appear that arrangements must be made for the revolving coils to cut as many lines of force as possible in the shortest possible time. This implies (1) that the armature should rotate very rapidly; (2) that it should be placed in a position where the field of magnetic force is very strong; (3) that it should consist of many turns of wire, each inclosing as much area as possible; and (4) it should offer a very small resistance to the current. These conditions are not all equally attainable at once. We will examine them separately.

(1). *The Armature should rotate very rapidly.*—The strength of the induced current being proportional to the rate of decrease in the number of lines of force that traverse the circuit, the advantage of rapid rotation is obvious. In the case of those machines in which the armature revolves in a magnetic field of constant strength (as in the case where the field magnets are of hard steel), the strength of the current is almost exactly proportional to the number of revolutions per second. But if the armature be very heavy, or the driving machinery unequal to its work, there is a limit to the speed that can be maintained with efficiency. The writer has seen a small Siemens generator driven at a speed of 2500 revolutions per minute, yielding a current of about 21 ampères, while in contrast to this Edison's large dynamo-electric generator exhibited at the Paris Exhibition produced a current of 900 ampères with a speed of only 350 revolutions per minute.

(2). *The Armature should be placed in a very Strong Field of Magnetic*

Force.—It is for this end that the field magnets are constructed to concentrate the lines of force as much as possible across the space where the armature revolves. In the case of the Gramme ring the iron in the armature itself aids in intensifying the field of force. Three years ago the writer of these lines insisted emphatically in the columns of *Engineering* on the necessity of making the field magnets of dynamo-electric generators on a more massive scale. Edison has done this on his large generator mentioned above, in which the field magnets weigh nearly 10 tons, and consist of seven cylindrical coils, 8 feet long, terminating in enormous blocks of soft iron as cheeks.

(3). *The Armature should consist of many Turns of Wire, each inclosing as much Area as possible.*—Each turn of the wire adds to the inductive effect, for if each cuts across the lines of force of the field there will be an electromotive force set up in each. If there are a hundred turns of wire in the coil that is moved, there will be a force urging a current forward a hundred times as great as if the coil consisted of but one turn. It does not follow that the whole current will be a hundred times as great, because the hundred turns will offer a hundred times more resistance to the flow of a current (supposing the wire to be of the same thickness as the "one turn"). Practice only can dictate the choice of the thickness of the wire and the number of turns. Where currents of very great electromotive force are desired a thin wire of many turns is right; but where (as in electro-plating) it is desired to have a great quantity of current with a low electromotive force, the turns are few and a very thick wire is used. Again, if the area enclosed by the turns is large, a great many lines of force can pass through them; but to make room for our large turns the magnet poles must be wide apart, and this makes the "field" weaker, as the lines of force are not so concentrated as before. It is here again a matter for experience to determine. One point may be noticed, however, namely, that if we try to double the power of a coil by doubling the diameter of the turns instead of doubling their number we enclose four times as great an area. In Edison's monster generator mentioned above as furnishing the extraordinary current of 900 amperes, it is not desired to raise the electromotive force much above 100 volts, and the coils are, therefore, comparatively few. And instead of being made of stout copper wire they are constructed of solid copper bars bolted round the periphery of a drum, so as to offer an excessively small resistance to the currents.

(4). *The Coils of the Armature should offer a very small Resistance to the Current.*—The importance of this rule is obvious to any one who is acquainted with Ohm's law. The waste of energy, occasioned by the heating effect of the current on every part of the circuit that offers resistance to the flow, is a sound economic reason for keeping down the useless resistance of the armature.

Lastly, of these considerations respecting the relation of the electric current to the mechanical energy spent in producing it, we would recall the all-important law of Joule, which is that the energy of a current is proportional to the square of its strength. If you can by any means double the strength of a current you will increase fourfold its power to do work. This law resembles the law in mechanical science to the effect that the energy of a moving body (or its *vis viva* as the old books used to say) is proportional to the square of its velocity. An example will illustrate the point. Suppose a cannon ball weighing 1 lb. to be shot out of a gun with a velocity of 100 feet per second. A certain quantity of energy in the form of the explosive activities of the gunpowder must be expended on it to give it that velocity, and by virtue of its velocity and its weight it is capable of doing a certain amount of destructive work. To shoot *two* such cannon balls at the same rate of 100 feet per second will obviously require the expenditure of twice as much gunpowder, and the two balls will do twice as much damage in the end. Now instead of sending *two* cannon balls at the same rate of 100 feet per second, let us send *one* cannon ball at the rate of 200 feet per second. Will the same quantity of gunpowder suffice? Will the effective work be the same? No, indeed. You will find that you want a *fourfold* charge of gunpowder to impart a *double* velocity; and that by virtue of the double velocity the destructive work will also be increased *fourfold*. Treble the velocity while the weight moved remains the same and you increase its effective energy ninefold; but then you will require a ninefold charge of powder to produce that trebled velocity. The energy of a moving body is proportional to the *square* of the velocity with which it moves.

Now in like manner the energy of the electric current is proportional to the square of the strength of the flow, that is to say is proportional to the square of the rate at which electricity is conveyed through the circuit. And as the heating effect of a current is proportional to its energy it follows that the heat produced by a current is proportional to the square of the strength of the current.

Again, it has been shown again and again, by experiment, that in a generator in which the magnets are either permanent or excited by a separate current, the strength of the current through a circuit of constant resistance is proportional to the speed of the machine, that is to say, to the velocity with which its armature rotates. Now, by the foregoing principle it is certain that the mechanical work done in driving the armature will be proportional to the square of the velocity of the rotation. It is therefore intelligible that the energy of the current should be proportional to the square of the strength of the current if the current be proportional to the speed. For, by the principle of the conservation of energy, the work which the generator will do can never be more than the work done by the engine in driving it, and should be precisely equal to it in amount if there is none lost wastefully in the process.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers. The Society met Wednesday evening, April 19, Maj. Geo. W. Dresser in the chair. Mr. John Bogart, Secretary.

Mr. Ricardo Orozco, C.E., of Mexico, exhibited and explained the Plans and Profiles of the proposed works of drainage of the Valley and City of Mexico. The explanations were translated by Mr. Theophilus Masac, C.E.

The City of Mexico is situated in a basin without natural outlet. The Lake Texcoco within a very short distance of the city, in times of flood, overflows and affects deleteriously the city, to such extent that its sanitary condition has become very bad.

A short distance further from the city are the lakes Chalco and Xochimilco which also overflow towards the city.

Three other lakes at more considerable distances are in the same basin. There are no natural outlets, only evaporation lowering the areas of the waters.

The extreme desirability of securing drainage from this basin has been long felt.

In the 17th Century, Senor Enrico Martinez, an Engineer under the Spanish authorities, constructed a tunnel partially through the Mountain Nochistongo, which, however, never was entirely completed. Many years afterward the Jesuit Fathers made an open cut down to the tunnel. This work cost a very large amount of money and many lives. Proper slopes were not maintained and the earth caved in frequently.

The drainage has never been properly kept up.

Senor Orozco's plan is to construct an open canal upon such a grade as will entirely drain the lakes Xochimilco, Chalco and Xaltocan, and also maintain at regulated surfaces the lakes Texcoco and Zumpango.

Through the City of Mexico are to be constructed sewers flushed by the waters from the lakes which are carried to a common conduit, where the sewage is purified by deposition, the solid matter to be used for fertilization and the water carried away in the canal. The whole length of the canal would be about 50 miles. Expense about $7,000,000.

Maps, Profiles and Plans executed in a remarkably fine manner were exhibited.

May 3, 1882.

The Society met at 8 P. M. President Welch in the chair and John Bogart, Secretary.

A paper on the Improvement of the Potomac at Washington, by Wm. R. Hutton, member of the Society, was read by the Secretary. The different plans proposed were described. Those of the Board of Survey of 1872, of a Committee of Taxpayers in 1877, of Col Abert in 1878, of the Commissioners of the District in 1879, and its modification in 1881, all preserve the main channel of the river on the Virginia side, and leave a large area of flat low land to be reclaimed along the present water front of Washington, virtually extending the city streets about three-fourths of a mile beyond the present wharves. In some of the plans a narrow channel adjacent to the present shore line is retained for a part of the lower city water front. The objections urged against these plans are their excessive cost; the removal of the water front too far from the business portion of the city; the increased difficulty of drainage; the reclamation of too much land of a character very expensive for maintenance, and in the project of the District Commission special difficulties connected with the proposed flushing basins.

The author advocates the deflection of the main channel of the river below Georgetown, across the flats to the Maryland shore, and its maintenance substantially along the present water line of the city. He claims that this is entirely practicable, that the low land left on the Virginia side will be less objectionable, that the deep channel close to the city will be of permanent value, that the sewage and drainage of the city will be much more easily disposed of; that there will be less danger of ice gorges, and that the cost will be moderate.

ENGINEERS' CLUB OF PHILADELPHIA.—April 1st, 1882.

President Rudolph Hering in the chair.

Mr. D. McN. Stauffer read a paper upon "Brickwork under Water Pressure."—During the construction of the tunnel under Dorchester Bay in Boston, it became necessary to construct a brick bulkhead that had to withstand the pressure due a water column, 162 feet high, and, as it was intended to shut off a leak amounting to 240,000 gallons per 24 hours, it had to be water-tight.

The tunnel section at the point selected for the bulkhead was practically 10 feet square. The bulkhead was built directly across the tunnel, 50 feet in front of the heading where the water was struck. Plank dams filled with puddle clay were first thrown across the tunnel, each side of the bulkhead site, and a 6 inch wrt. iron pipe used to carry off the water during construction—the pipe being built into the brickwork. An arched form was adopted, 4 feet thick at the crown and 2 feet rise in a span of 10 feet. Hard, burned bricks were used, laid in mortar made of one part Eng. Portland, one part Newark Rosendale, and two parts clean, sharp sand—a compound found equally as strong as Eng. Portland and sand, one to one, and having the advantage of working smoother on the trowel, and adhering better to brickwork in wet places. Skewbacks for the arch were roughly picked out in the rock at the sides. After the cement had set, the water was shut off by screwing a cap on to the outer end of the 6 inch cap The pressure against the wall was $72\frac{1}{10}$ lbs. per square inch, or abont 519 tons distributed over the face of the bulkhead. The wall was tight for about 48 hours; then the water came through the *brick* itself, rather than through the joints, in amount equal to one-half the original volume.

The water was let off and a second experiment tried. The main wall was torn down sufficiently to allow men to pass behind it, and a second wall only 12 inches thick was built back of the first, and 2 feet distant. The space between these walls was well rammed with puddle clay, extending to the rock on all sides. The second wall was made purposely light, as its yielding to the pressure would only more effectually consolidate the clay between it and the unyielding wall in front. The bond used in the main wall was one so laid, that there were no continuous horizontal joints through the wall.

The result of the last construction was to completely shut off the water from this leak, at a great saving of fuel and pumps. The Dorchester Bay tunnel is 7,000 feet long, with its average invert grade 148 feet below low tide mark in the bay under which it passes. The tunnel is driven through a formation of clay, slates, and conglomerates for its entire length; rock, very seamy, and much water encountered.

Mr. E. V. D'Invilliers read a paper by Mr. O. B. Harden, of the Pennsylvania Geological Survey, entitled "Topographical and Geological Modelling," in which the method pursued by the survey was explained, and the text illustrated by photographs and models The requisite for a good model is a good contour map of the ground to be illustrated, with contours, 10, 20 or 100 feet vertically apart. The lumber used by cigar-box makers is best suited for modelling—of a thickness required by the vertical scale. On a scale 1,600 feet to an inch the boards will be $\frac{1}{16}$ of an inch thick and represent 100 feet in height. The contour line marked upon the base and the one next above it are traced upon boards cut the exact size of the base, and the lowest or outer one of the two is sawed through by a jig saw, the upper or inner one serving to mark the place for the next succeeding board. These are nailed on with sprigs—glue being used where from the sharpness of a piece—a nail would split the wood. The wooden model is then waxed—the wax being worked down until just the edges of the boards are seen, and until it presents a smooth appearance and fac-simile of the topography. The model is then rubbed with linseed oil and is then ready for casting in plaster of Paris. Care should be taken to get the oil in on the low places, as on this depends the facility with which the negative can be removed after the setting of the plaster. A cast is then made with plaster of Paris, filled in around a frame to the requisite thickness—and, after being allowed to dry for about an hour, it is removed from the original, smoothed up with a file or knife edge and coated with shellac varnish. From this cast a positive is made—pursuing the same method as before—and is dried and scraped. The sides are smoothed up for the sections, and after being varnished the model is ready for the coloring—representing the different geological formations. Streams and geographical features being added, the model is complete.

ENGINEERING NOTES.

THE NEW YORK DOCKS.—By a resolution adopted by the Dock Commissioners, in July last, the following queries were submitted to an invited board of consulting engineers:

1st. Is the wall now being constructed the most desirable one for all the interests of the city, for the section of the water-front under improvement?

2d. If it is not, what changes in its construction should be made to make it so?

The Board consisted of General John Newton, General Q. A. Gillmore, William E. Worthen, Esq., the Engineer-in-Chief of Docks.

George S. Greene, Jr., was requested to afford all facilities in his power for the examination.

The following is an abstract of the Report:

To the Commissioners of the Department of Docks of the City of New York.

GENTLEMEN: Agreeably to the instructions of your letter of September 14, 1881, and your personal explanations in the interview of the 23d of the same month, we have made "a thorough investigation of the manner of constructing the wall now being erected by the Department," and, as pertinent to your inquiries, an examination of the walls already built by the department on the same general plan.

We have seen the manner in which the concrete blocks were made, the class of materials used, the proportions in which the cement, sand and broken stone were mixed, their deposit in the boxes, and the manner in which the manipulation was conducted, and have tested the absorption of salt water by the concrete. [Details of the examination omitted.]

From our experience and late observations on the old work, and from the investigations on the work now in progress, we feel prepared to answer the questions of your letter of September 14.

In answer to the first query, we would say that this wall, taken as a whole, is the result of practical growth from the first inception of the work. It combines, in a suitable measure, the necessary elements of strength, endurance and stability; it is ample in its dimensions, has a liberal factor of safety, is not difficult of construction, and appears thus far to have been well and faithfully built. We do not therefore recommend, as necessary, any essential changes of plan, but there are certain modifications which we do recommend, and which will be found in detail in answer to your second query.

In answer to the second query, we are of the opinion that the concrete used in the blocks, as well as that formed *in situ* as backing, is unnecessarily rich in Portland cement, and that the best varieties of natural cement would answer very well for this concrete.

If natural cement be used, the proportions to be as follows:

Cement, 1. Sand, 2. Broken stone, 5.	For the base of the blocks up to the height of one foot above the chain hole.
Cement, 1. Sand, 3. Broken stone, 6.	For the balance of the concrete block and the backing.

If Portland cement be used, the proportions may be:

Cement, 1. Sand, 2¼. Broken stone, 6.	For the base of block to height above indicated.
Cement, 1. Sand, 3. Broken stone, 7.	For balance of block and backing.

We also recommend the use of a machine for mixing the concrete, whatever kind of cement be used, and that the blocks be kept, before they are put in the wall, at least sixty days, shaded from the direct action of the sun.

The rip-rap in front of the wall covers the head of the piles to about the depth of two feet; whilst in this condition it is ample protection for the piles from the *teredo;* but should the dredging of the slips be carelessly done, and the excavation be carried into the rip-rap, it will settle away from the walls, and the piles will be denuded, and this may obtain from settlement of the rip-rap without dredging, from the action of the screws of steamships or other causes; and if the piles be exposed, they might soon be destroyed by the worm. To obviate this, we recommend that the base of the concrete block be established at a level of 17 feet below mean low water mark, that is, adding 1 foot 9 inches to the depth of the bottom of this block, preserving the same curve of outer face, and the vertical rear; the position, as well as the bulk of the rip-rap, being kept as at present.

The thickness and weight of the revetment wall, increased by the expedient of your engineer, by the inexpensive filling of cobble stones between the piles, and forming a part of the wall, afford considerable resistance to the earth-thrust of the back-filling.

The rip-rap is also indispensable to prevent the heeling of the mass outwards around a lower point, and in this office, the bracing piles also lend their assistance. The weight of the wall is directly supported by the skin resistance of the piles, and by the mass of cobble stones resting upon the mud. Contributing in considerable measure to this, the rip rap extends the bearing surface on each side of the wall, and acts as braces to prevent overturn or settlement.

The whole mass resting thus upon a yielding foundation, and to be regarded, in some sense, as floating upon it, will, it is thought, be subject to settlement, but not considerable, and experience has shown that the whole mass will substantially settle together, with little variation, and the front of the revetment will retain its *batir*.

With walls thus supported on mud, it is always desirable to establish as great a symmetry of mass as the other conditions imposed on the structure will admit, in order that the settlement, if any, should take place without tilting.

In this view, we would recommend that the rip-rap on each side of the wall should be in nearly equal masses. Some excess may be given to the portion in the rear of the wall, as the extra thrust may be met by the inclined piles.

We recommend that the ballasting with small cobble stones, the placing of the concrete block, and rip-rap work, be completed as much in advance of the other work as possible, in order that settlement may take place before the wall is completed.

For back-filling, under these circumstances, any material will answer; sweepings of streets, collections from houses, ashes, garbage beneath the water, and even dredgings, if not in a liquid state, and all done slowly, working from wall toward shore.

We recommend that where no wall has yet been commenced, and where it will not interfere with wharfage, an experiment be made of filling in broadly on the line of the wall before doing anything else, as by this means the soft mud will be forced out, or in some degree consolidated by its mixture with firmer material.

The present cross-section of the wall, as designed by your Engineer-in-Chief, we regard as founded on correct principles of stability and economy, and the modifications we suggest seems to us to improve it without changing the ideas characteristic of the plan.

*Respectfully submitted,

(Signed) JOHN NEWTON.
Q. A. GILLMORE.
WM. E. WORTHEN.

ORDNANCE AND NAVAL.

KRUPP'S MUZZLE PIVOT GUN.—The Germans seem determined to be ahead of this or any other country in their practical efforts towards the adoption of every new idea in scientific warfare that will give them power in Europe. Once more Herr Krupp has come to the front. This enterprising maker of warlike material has recently conducted a series of experiments with a new kind of gun and shell. The gun is on the muzzle-pivoting system, and the shell has been especially designed for torpedo effect, that is, to burst on penetration of armored ships with a result similar to the explosion of a torpedo. The idea of the muzzle-pivot gun is not novel. It has been known to our War Office authorities for some years; but they have not thought proper to thoroughly or practically test its utility. They have during late years been either allowing what little inventive faculty they possess to lie dormant, or have been content with watching the operations of other powers in the direction of improvements in ordnance and other warlike material, and then copying their results. Unfortunately, the latter has only become too patent, and the position which Great Britain has consequently slipped back to is now admitted by every practical or scientific person. Herr Krupp's recent experiments at Meppen were considered to be highly satisfactory, and quite sufficient to justify the great German manufacturer of weapons in taking immediate measures for the production of larger guns and shells than those tried. The gun experimented with was of 21 centimeter caliber, with a long shell having a tremendous bursting charge, so arranged that the shell should explode only after penetrating some distance into the armor plating. The gun's muzzle-pivot is carried down into a socket fixed in the hold of a vessel in such a way as to prevent the slightest recoil even with the heaviest charge. Herr Krupp's gun was worked during the trials with great ease and certainty of aim, and obtained for the shell a very high velocity. This description of weapon has been designed for gunboats built to carry guns up to 40 centimeters. These gunboats are to be of light draught, high rate of speed, and exceedingly handy. In fact, two or even three of such armed boats would be very ugly customers for a first-class armored ship to cope with, owing to their rapid power of maneuvering, and their small size rendering them difficult to hit. Their cost would be but an eighth or a tenth of a first-class ironclad. The Germans are certainly a very practical race. A good idea once conceived and well considered in all its bearings, they then do not take very long to work it out. We shall hear more ere long of Herr Krupp's muzzle-pivoting guns and torpedo shells.

RAILWAY NOTES.

A CORRESPONDENT has sent the London *Times* the following table, showing what may be called the maximum speed accommodation to or from London, provided by nine different railway companies, and the fares per mile at which they respectively provide it. Wherever the length of the line is sufficient the run taken is considerably over 100 miles, with at least one intermediate stoppage:

No	Railway.	Test Station.	Miles from town	Speed. Miles per hour	1st Class Fares. Pence per mile.
1	Great Northern	York	188	48.000	1.755
2	Great Western.	Bristol	118	45.884	2.652
3	London, Chatham and Dover	Dover	78	44.571	8.076
4	Midland........	Derby	127	44.046	1.606
5	London and N. Western.....	Crewe	158	43.880	1.835
6	South-Eastern.	Dover	76	42.617	8.157
7	South-Western	Sherbo	18	40.227	2.440
8	London, Brighton & S.-coast.	Brighton	50	40.000	2.950
9	Great Eastern.	Norwich	126	86.000	2.000

It is obvious that the shorter lines—the London and Brighton, the Chatham and Dover, and the South-Eastern—are unduly favored on this principle, and occupy a higher place than they deserve, and this is especially remarkable with respect to the Great Western, which runs distances a little over that chose, at an equal or greater speed than that given for the Great Northern. The fares of the two latter speak for themselves, and it should be remembered that the boat trains—for which credit has been given—start at very inconvenient hours for passengers, and are almost the only good trains which they run. The performance of the Great Northern and the fares charged are astonishing. The Great Eastern now runs some good trains, and the Midland trains are good and the fares low.

IRON AND STEEL NOTES.

MALLEABLE CAST IRON AND THE ANNEALING OF STEEL.—By M. Forquignon—Since the time of Reamur who, in his classic memoir of 1722, first formulated the principles of the operation, the manufacture of malleable iron has become of great importance, but, in spite of the improvements introduced in its production, the chemical history of this product has still to be written.

Up to the present all that has been known is that malleable iron is cast iron deprived by oxidation of a part of its carbon, and thus approaching the state of steel or wrought iron.

To fully understand the experiments, attention is drawn to the following points :—

1st. All pig iron is not equally adapted for the process. Grey or manganiferous pig gives bad results. White pig made from the purest ores is preferable.

2nd. The softening of the iron applies nearly exclusively to small objects ; the operation does not succeed well in the case of objects more than an inch in diameter.

3rd. The time for baking varies, according to size and quality required, from twenty-four hours to six days or more.

4th. The temperature of the furnaces is generally bright cherry red.

5th. Peroxyde of iron (powdered red hæmatite) is almost the only substance now used as cement.

The object of the author has been to determine the chemical composition and tensile strength of numerous samples of malleable cast iron differing from one another either in composition, in place of manufacture, or in the treatment they had undergone, the effects of different substances used as cement, and also to find out in what way malleable iron differs from steel, wrought iron, and cast iron In order to attain the objects in view, the author conducted a series of analyses of cast iron before and after its transformation, and experiments as to its physical properties, especially its elasticity.

The first series of experiments were made with cast iron heated in contact with powdered hæmatite. Secondly, heated with various substances, such as charcoal, iron filings, silica, quicklime, calcined bones in powder, colcothar, and marine salt. Thirdly, in contact with various gases, such as hydrogen and nitrogen. These experiments proved that the softening of the cast iron does not result from the oxidation of its carbon, but that this oxidation, when it does take place, is purely accessory. By the simple action of a temperature sufficiently high, but inferior to its melting point, the white cast iron is destroyed or becomes carbonized, so to speak. A veritable amorphous graphite belonging to a particular variety, is deposited abundantly through the whole mass of the bar, sometimes in the form of little visible agglomerations, sometimes disseminated or intimately mixed.

Instead of a combination there is now only a mixture of free carbon and free iron. The cast iron, deprived of a part of its combined carbon, is softened, and its resisting properties are greatly modified.

The action ends here if the heating takes place in an inert substance like charcoal, but if the iron is in contact with a substance capable of burning or absorbing the carbon, a secondary reaction takes place, the free carbon on the surface is burnt, a portion of the graphite from below comes to the surface and in its turn is destroyed. Manganese in the iron prevents softening by opposing the formation of graphite.

The author sums up as follows :—

1st. A cast iron really malleable always contains amorphous graphite.

2nd. A cast iron may lose carbon and still remain brittle if graphite has not been formed, or if the existing quantity of graphite is not increased.

3rd. A cast iron can become malleable without losing a sensible portion of its total carbon.

4th. If silicon is added to a manganiferous cast iron, the latter is improved by the reheating.

5th. Hydrogen and nitrogen combine with the carbon in the cast iron, which in this case alone can become malleable without the production of graphite.

6th. The breaking weight is always more than doubled, sometimes more than quadrupled, by the reheating; it increases with the length of the heating very rapidly at first, very slowly afterwards. Finally, malleable iron occupies a place intermediary between steel and grey pig; it differs from the latter by the special nature of its amorphous graphite, and by its great tenacity, and from the former by its large quantity of graphite.

A series of experiments with steel similar to those with cast iron, viz. reheating in contact with various substances, confirmed the conclusions arrived at above.

The last few pages of this paper contain a description of a small furnace by which very high temperatures can be easily obtained.—*From Abstracts of Institution of Civil Engineers.*

RIVETING.—The direct crushing strength of wrought iron is generally about equal to its tensile strength, in the case of short isolated bars, but the metal around the rivet hole in a boiler plate is in a different condition, being supported by the surrounding unstrained metal of the plate. Direct experiments which have been made on plates, with the object of ascertaining the crushing strength under these circumstances, show on an average the crushing resistance may be taken at twice the shearing resistance, consequently, in order that the shearing resistance of the rivet and the crushing resistance of the plate may be equal, the area of the rivet shank should be equal to twice the product of the thickness of the plate multiplied by the diameter of the rivet. Deducting from this the value of the diameter of the rivet in terms of the thickness of the plate, we find that it should be two and one-half times the thickness of the plates. This is the theoretically correct size of the rivet, but practically it is found necessary to make the rivet somewhat smaller, for the following reasons: First, if the rivet is given the above size, when we reach thicknesses of plate above seven-sixteenths of an inch, the rivet becomes too large to be properly closed by hand riveting; second, the material of the plate is somewhat injured by the punching, and cannot always be relied upon to bear twice the shearing strength; third, it would be necessary to space the rivets so far apart, to retain equal strength of plate and rivet, that it would be impossible to make a steam and water-tight joint; fourth, the plate is more apt to be reduced in thickness by corrosion than the diameter of the rivet is, so it is found better to give it an excess of strength at the start to allow for wear. For these reasons the diameter of the rivet is made as small as twice the thickness of the plate, and even smaller for the thicker plates. By placing rivets in two rows, which is equal to one-half of the pitch, a much tighter and stauncher joint can be obtained than is possible when they are placed in the form of an equilateral triangle, as they generally are, which necessitates a reduction of the pitch to obtain a tight joint.

BOOK NOTICES.

PRACTICAL MICROSCOPY. By George E. Davis, F. R. M. S. London: David Bogue. Price $3.00.

The rapid increase in the use of the microscope, as a means of research, has led to a demand for good manuals of instruction.

This treatise is not so suitable for the beginner as some books already in the market, but it will prove serviceable to the worker who is interested in the relative merits of the various objectives and stage fittings, about which the more experienced microscopist is likely to be interested. The instruction in regard to preparing and mounting specimens is particularly good. The illustrations are fairly abundant, and only fairly executed.

PRACTICAL VENTILATION AND WARMING. By James Constantine. London: J. & A. Churchill. Price $2.40.

The principal merit of this book lies in the descriptions of the heating and ventilating equipment of several large public buildings, and as those examples have been selected in which the methods have received public approval, they are presumably safe guides.

Too much space is given to the description of heaters and stoves, which are illustrated by some cuts of inferior quality.

The usual essay on the constitution of the atmosphere, and Dr. Angus Smith's conclusions about the normal proportion of carbonic dioxide of course begins the treatise.

ELEMENTS OF WAVE MOTION RELATING TO SOUND AND SIGHT. By Peter S. Michie, Professor of Natural and Experimental Philosophy in the U. S. Military Academy and Brevet Lieut. Colonel U. S. Army. New York: D. Van Nostrand.

This text-book was prepared expressly for the Cadets of the West Point Military Academy. It is therefore adapted to the proficiency of students who have completed the study of Elementary Mathematics, so far as to include the calculus, and have been through a course in Analytical Mechanics.

This treatise is divided into three parts, viz.: Wave Motion, Acoustics, and Optics.

As the author explains in his preface he has been governed in the arrangement by the necessities of the case and the restrictions of the course of study. He has therefore deemed it advisable to deduce Fresnel's Wave Surface as expeditiously as possible, incidentally establishing the essential principles of undulatory motion, common to sound and light.

Acoustics is made subsidiary to Optics by utilizing its numerous illustrations in vibratory motion, so that the laws of this motion may be more clearly apprehended in the subject of light.

The course in Optics includes a discussion of the essential principles of the deviation of light by lenses and mirrors, and the application of these principles to Telescopes, the Spectroscope and the Polariscope.

The book will be widely read by other students than those at West Point, because it is a prescribed text book at the leading Scientific School of the land, and it is more than likely that Prof. Michie's course in Wave Motion will determine the course of study in our higher Technical Schools.

HANDBOOK OF THE POLARISCOPE, Adopted from the German of H. Landolt. By D. C. Robb, B.A., and V. H. Veley, F.C.S. Price $3.75.

This thoroughly scientific treatise is dividde into the following distinct sections:

General Aspects of Optical Activity, Physical Laws of Circular Polarization, Specific Rotatory Power, Process of Determining Specific Rotation, Practical Applications of Rotatory Power, Rotation Constants of Active Substances.

As might be supposed the practical applications relate largely to Sugar Analysis.

The illustrations are numerous and good and the typography is excellent.

MISCELLANEOUS.

ELECTRIC LIGHT *v.* GAS.—The controversy as to the respective cost of gas and the electric light, if it has not yet been definitely settled, is, we think, on the road towards solution. The figures now vouchsafed to us by the City authorities may, we take it, be relied upon. We learn that at the meeting of the Court of Common Council held last week Mr. Felton, chairman of the Court of Sewers, stated that, of the three electric lighting systems now being tried experimentally in the City, that of the Brush was about the same price as gas, the Lontin was twice the cost, and the Siemens nearly four times the cost. The Brush patentees had, however, given notice to increase their contract price ten per cent., and the Siemens authorities also contemplated increasing their estimate to five times the cost of gas in the same area. As to the new effective gas lighting in Fleet street, he might state that it was over four times the cost of the Brush system in the same district. In reading the above business-like statement, we arrive at two conclusions. In the first place, the effective mode of lighting up the City by arc lamps is nearly as cheap as the indifferent illumination produced by gas. In the second place, it is equally certain that, if gas-light is to be as effective in the open air as the electric light, its cost will be at least three times that of, say, the Brush light. It must, however, be admitted that the latter is the best and cheapest arc light we have at present, its superiority and consequent cheapness being principally due to the excellent quality of the carbons used by the company which owns the light.

VAN NOSTRAND'S

ENGINEERING MAGAZINE,

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Published on the 20th of the month at $5.00 per year.

The January number of this MAGAZINE, for the year 1882, begins the Twenty-sixth Volume. Beginning as an Eclectic Journal, and presenting almost exclusively matter selected from current literature, it has gradually become the chief medium through which the leading writers on engineering subjects can best present their original essays to American readers.

The attitude of the MAGAZINE has been, and will continue to be, that of a journal of original and selected papers upon subjects relating to modern advanced Engineering. Theoretical and Practical Essays are alike presented in its pages, although the latter largely out-number the former, as best suited to the tastes and demands of the American Engineers. Some of the most valuable contributions to the literature of technical science within the last few years have been first presented in these pages.

Among the more extended original contributions to the later volumes may be cited Transmission of Power by Wire Ropes—Momentum and Vis Viva—Rapid Methods of Laying out Gearing—Strength of Long Columns—Suspension Bridges of Any Degree of Stiffness—Acoustics in Architecture—Continuous Girders—Geographical Surveying—Mathematical Theory of Fluid Motion — Thermodynamics—Cable Making for Suspension Bridges, &c., &c.

To the above may be added the following valuable essays, translated from foreign sources, which have first appeared in these pages: Linkages and their Applications—The Origin of Metallurgy—The Theory of Ice Machines—Incandescent Lighting.

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