

ELECTRIC LIGHTING
WITH
INSTRUCTIONS
FOR THE
PROPER INSPECTION OF EQUIPMENTS.

ELECTRIC LIGHTING,
AND THE
UNDERWRITERS' STANDARD REQUIREMENTS

IN REFERENCE THERETO,

WITH INSTRUCTIONS FOR THE PROPER INSPECTION OF ELECTRIC
LIGHT EQUIPMENTS,

ILLUSTRATED,

PREPARED BY REQUEST OF THE

NATIONAL BOARD OF FIRE UNDERWRITERS,
AND THE
UNITED FIRE UNDERWRITERS IN AMERICA,

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INTRODUCTION.

The nature of Electricity, or the final cause of those phenomena we call electric, is something about which we are absolutely ignorant, although we know so much about the modes of action, and have made such great and varied use of this unknown agency.

In order, however, to discuss the actions of this force with brevity and precision, and to think of it with clearness, we must have at least some provisional theory or hypothesis, even if we do not accept the same as a true expression, and only regard it as a convenient assumption.

The most convenient assumption of this nature which has been proposed and generally accepted is that of the electric fluid, and this accordingly I shall use in the present discussion.

I shall, moreover, for the sake of brevity, omit all reference to that condition of electricity known as "static" or frictional, and confine myself entirely to dynamic or galvanic electricity—in other words, electricity in motion.

THE ELECTRIC FLUID HYPOTHESIS.

The above hypothesis assumes that all material substances contain large quantities of an immaterial fluid, which is without weight or volume, or any other property of matter, but which is capable of being put in motion with more or less ease in various substances, and when so moving, produces certain effects which will be explained further on.

The bodies in which this fluid can be made to move easily are called conductors, and those in which it is difficult to make it move, are called non-conductors or insulators. Among the first we have the metals, solutions of chemical salts, moist earth and the like ; and among the latter, glass, gutta-percha, dry earth and the like. It should, however, be remembered that this is only a distinction of degree, and that there are no perfect conductors and no absolute insulators.

The very best conductor requires some force to make the fluid move in it, and the fluid may be made to move in the best insulators if sufficient force is supplied.

Again, bodies cannot be divided into distinct classes of conductors and insulators, but can only be arranged in a series in which we pass by small gradations from the best conductors to the best insulators through every possible intermediate degree. The following table gives a series of several familiar substances, arranged in this way :

Worst Conductor—

Dry Air.	Dry Paper.	Charcoal or Coke.
Ebonite.	Porcelain.	Mercury.
Paraffin.	Dry Wood.	Lead.
Shellac.	Dry Ice.	Tin.
India-rubber.	Stone.	Iron.
Gutta-percha.	Pure Water.	Platinum.
Resin.	Melting Ice.	Zinc.
Sulphur.	Rarified Air.	Gold.
Sealing wax.	Sea Water.	Copper.
Glass.	Saline Solutions.	Silver—
Wood.	Acids.	<i>Best Conductor.</i>

This fluid can only move continuously in a conductor, if a closed circuit is formed. Thus it will not continue to move or form a current in straight wires, whose ends are separated. The

wire must be bent into a ring, or its ends connected by another conductor.

When this fluid is moving through a good conductor—such, for example, as a copper wire—it moves through the substance of the metal; it does not move like water in a pipe, but like water soaking through sand. Its ease or difficulty of passage will then depend on the area of cross section of the wire or other conductor.

If the conductor is a good one, there will be but little resistance opposed to the passage of the fluid; but whatever resistance there is, will cause a corresponding development of heat, just as if there was a mechanical friction between the fluid and the particles of the conductor. This heat will always vary with the amount of current passing and the resistance of the conductor.

If the conductor is a good one, it will convey a large amount of current easily, with very little heating. If the conductor is less good, it will be more difficult to force the same amount of current through it, and more heat will be developed, and so on as the conductor is worse and worse, either by being of a worse material or by being smaller in cross section, more and more heat is produced, provided that there is power enough to force the current through, until at last we may have a fine wire heated red or white hot, or even fused and dissipated in vapor.

The force needed to drive the fluid through conductors, good or bad, is called electro-motive force, and we may think of it as a velocity imparted to the fluid by any of the means employed for that purpose, or as a pressure or height of level or head, caused in some reservoir of the fluid, by the same means (*i. e.*, the galvanic batteries or dynamo-electric machines) used to produce the electric current.

The means of putting the electric fluid in motion are very various, but we will here consider only that involved in the operation of the dynamo-electric machines.

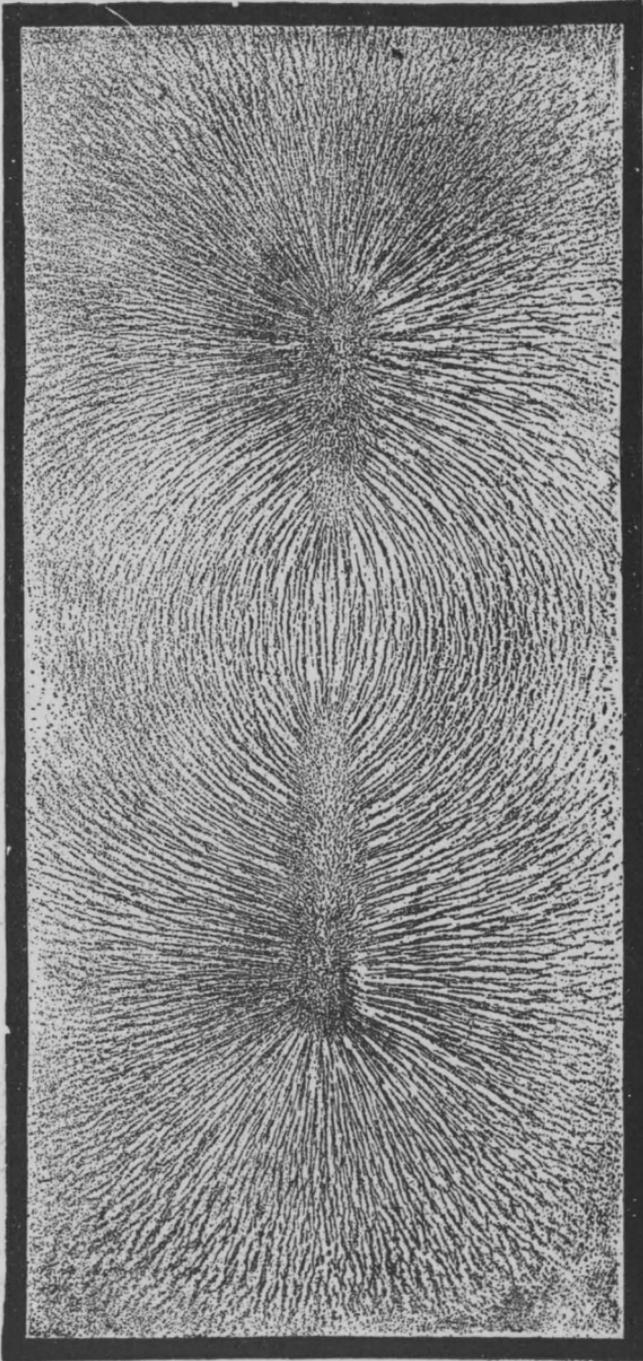


Fig. 1.
LINES OF MAGNETIC FORCE.

When small particles of iron are brought near a magnet, they tend to arrange themselves in certain lines and curves, such as are shown in Figure 1, page 6. These have been called "lines of magnetic force."

It was first shown by Faraday, in 1830, that whenever a conductor, such as a copper wire, was moved near a magnet so as to cut across any of the directions indicated by these lines, the electric fluid in the wire was put in motion.

Working upon this principle, various inventors from that time to this have developed different forms of machines for the production of electric currents, by the motion of conductors across the lines of force surrounding magnets.

If the magnets used are permanent, the machines are called magneto-electric, and when the magnets are temporary, *i. e.*, produced by electric currents in wires wound around them, they are called dynamo-electric machines.

The source of the electric current in these machines, as we have already stated, is the motion of conductors across the lines of magnetic force proceeding from magnets.

In these machines the conductors consist of coils of copper wire, or of copper strips or bars, so arranged, that they can be rapidly rotated as near as possible to the poles of powerful magnets.

These coils of wire, so arranged, are called "armatures;" they are usually wound on cores of soft iron, which serve to concentrate the lines of force on the surrounding coils, and thus increase the effect.

As an example of these armatures, we may select

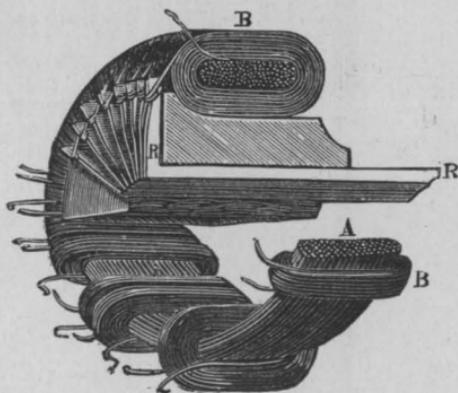


Fig. 2.
GRAMME ARMATURE.

that of the Gramme machine, shown in a partly dissected condition in the accompanying cut.

When in position it forms a solid ring, with the coils closely packed, as in the upper part of the figure, and the core of iron, A, constituting a closed annulus, around which the coils are wound. A shaft passes through the centre, and serves to support and rotate the ring armature.

The entire machine is shown in the accompanying figure, where the armature is seen in the middle, with the electro magnets above and below. The poles of these magnets are at their middle parts, and are extended so as partly to surround the armature.

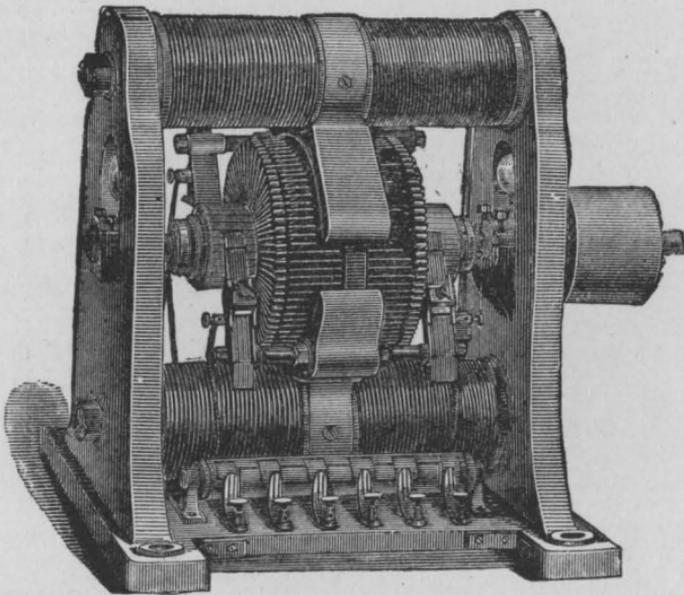


Fig. 3.

THE GRAMME MACHINE.

The current is taken from the wires by means of metal strips called "brushes," which press on metal strips leading from the coils, and arranged around the shaft, and called "commutators."

A single wire, of a certain size, moved at a given rate across lines of magnetic force, or, as we say, "a magnetic field," of a certain intensity, will have a certain amount of motion given to its electric fluid.

If the wire moves faster, or if the "field" is stronger, or if two or more wires are connected end to end, as are the successive turns of wire in a coil, the propelling power will be increased. Therefore, the more turns there are in each coil or bobbin, the greater will be the velocity, or pressure, or head of the current produced. If, however, as must generally be the case, we secure more turns in the coils by using smaller wire, then by this we shall diminish the quantity of the electric fluid set in motion.

When, therefore, we require electric currents to overcome great resistances, we must have many turns of wire in the armature; but when we want great quantities of fluid, we must use very thick wires or even bars of copper, and in this case cannot easily have a high velocity or pressure or "head" in the current produced, because if the bars are large we cannot have a great many of them or a great many turns of thick wire on the armature of the machine.

EFFECTS OF THE ELECTRIC CURRENT.

The effects of the electric current, with which we are here concerned, are its production of light and heat.

As I have already stated, an electric current always produces some heat, no matter how good the conductor; but if the conductor is abundant, this heat will be so small that it will be readily lost to the air and surrounding objects, and will not be perceptible. If, however, in any part of a circuit a relatively bad conductor is found, then a greater amount of heat will be there developed. This increased resistance may be occasioned by

various causes. Thus a portion of a circuit may consist of wire much smaller than the rest, or two pieces of wire in the circuit may be badly joined, so that at the imperfect contact a high resistance is found. There is also a special means of producing a high resistance in a circuit deserving of special mention.

FORMATION OF AN ELECTRIC ARC.

If a conductor, through which a powerful electric current is passing, is cut or in any way divided at any point, and the separated parts are gradually drawn asunder, the electric fluid will jump between the ends, carrying with it particles of the conductor and also reducing some of it to vapor. Under these circumstances, the heat produced at this point is the most intense obtainable by artificial means, not only melting but vaporizing the most refractory substances.

This flow of electricity under these conditions, between separated points in a circuit (called electrodes), is known as the electric arc. When the separation is made between rods of dense carbon, it is largely employed as a source of light, which is called the "arc light." To maintain this light for any considerable time, means must be provided whereby the carbon electrodes shall be made to approach each other as they burn away, for, owing to the intense heat, even the hardest varieties of carbon burn in this arc, and the positive pole is besides rapidly disintegrated by the tearing off of particles from it through the action of the current.

The carbon rods generally used are coated with a thin layer of copper to increase their conducting power. This at once melts and burns off from the ends, and forms globules and rough projections above and below, so that the electric arc between the electrodes of an ordinary electric lamp, when seen through a dark glass, has very much the appearance shown in the accompanying figure, on page 11.

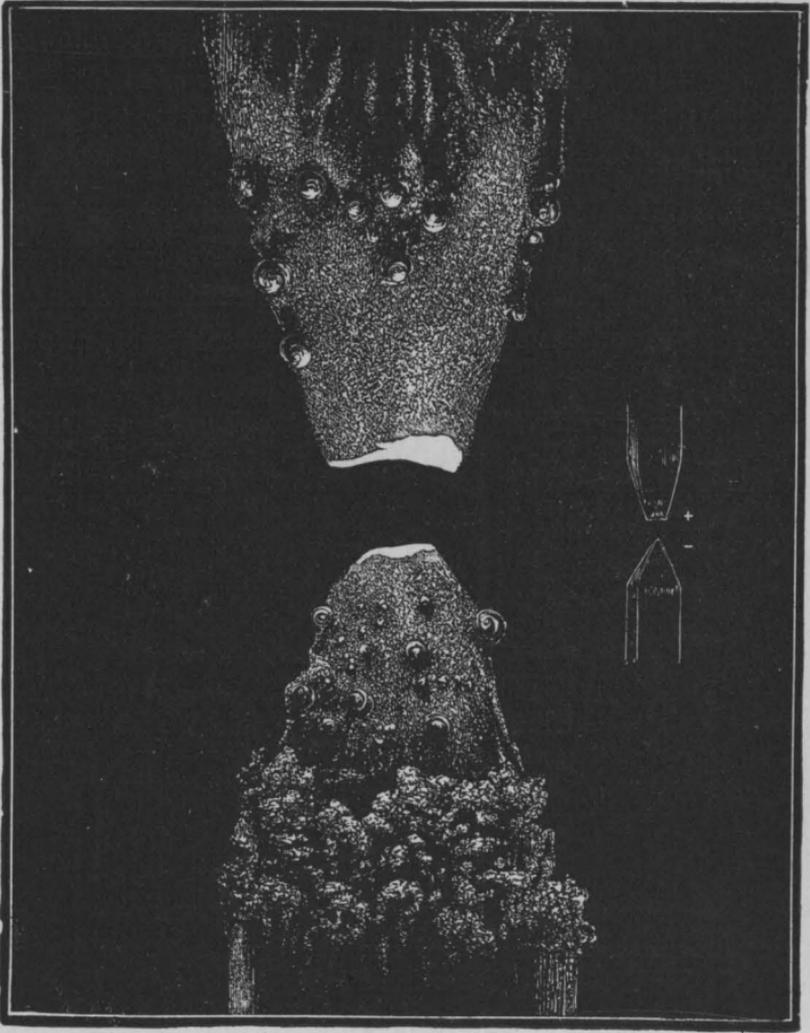


Fig. 4.

THE ARC LIGHT.

To drive an electric current across the gap between the electrodes requires, as might well be imagined, a considerable velocity or head; and as these lights are always run in successive series (*i. e.*, with the same current running from one to another), a

machine to operate several must be so constructed as to give a current of high velocity or head. It is to be observed, however, that the quantity of fluid needed for any number of such lamps in one circuit is no greater than for one, as the fluid simply runs out of one into the next, and so on.

It is manifest that the formation of an electric arc need not be confined to an arc lamp, but may take place with disastrous effect wherever the circuit is broken under certain conditions, or wherever two portions of it touch for a moment and then partly separate.

The other property already mentioned, of heating a small conductor forming part of a circuit, has also been utilized as a means of producing light.

In this case, a fine filament of carbon is secured in a glass globe totally deprived of air, and, being heated by a current passing through it from wires sealed into the globe, glows and gives light. This arrangement constitutes the incandescent light.

The electro-motive force needed to run the incandescent lamps is not more than that required for one or two arc lights, and as the former are always run in multiple arc—*i. e.*, the current runs in a series of parallel streams through all the lamps supplied by the machine—it follows that the machines used for incandescent lamps must give currents of large quantity, but not of great velocity or head, or, as it is called, “electro-motive force.”

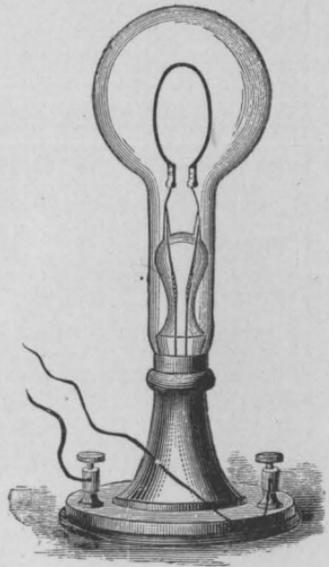


Fig. 5.

INCANDESCENT LAMP.

Having now considered, in a general way, the action of electricity as it is developed in electric currents, such as are used for purposes of illumination, we will take up the matter more in detail, and to make our ideas more definite, will compare the electric actions, as we proceed, with the analogous ones of water flowing in conducting pipes when propelled by pumps.

Suppose that we had a pump connected with a system of pipes running out from the pump on one side, branching and subdividing into various lines, but reuniting so that they all came again back to the pump on the other side, and that the pump and system of pipes was full of water. Now, if the pump is worked, the water will continue to flow through all the pipes as long as the pump moves. Moreover, the following things will be true in regard to this system :

First.—The amount of water flowing through any one of several circuits will be to that flowing through any other circuit inversely, as the resistance offered by the respective circuits to the flow.

Thus, suppose there were two branch circuits, one of which opposed the flow of water through it twice as much as the other, then, clearly, this circuit of double resistance would carry only half as much water as the first.

In the case of the electric circuits this resistance will vary directly with the length of each circuit, and inversely with its cross-section of the material in the same; and directly with the "specific resistance" of each material, where the circuits are of different material.

Thus let A represent an electro-motor, or apparatus of any sort, for producing a current of electricity, and A, B, C, D, E; A, F, G, H, I; and A, J, K, three circuits of various sorts. Then suppose A, B, C, D, E and A, F, G, H, J are both of the

same copper wire, but that the latter is twice as long as the former; then the quantity of current flowing through the latter would be half that flowing through the former. To make the quantities in these circuits equal while preserving their difference in length, we must double the section of the longer wire, which is the same thing as doubling its weight, or to get an equal current through a circuit twice as long we must put four times as much metal in the conductor, if everything else remains the same.

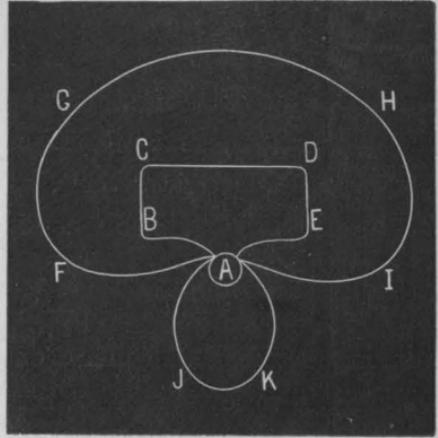


Fig. 6.

If the circuit indicated by A, J, K is supposed to be of iron wire equal in length and section to the copper wire A, B, C, D, E, then the resistance of A, J, K will be seven times as great as the other, and the current passing through it will be but one-seventh of that traversing A, B, C, D, E, because the "specific resistance" of iron is seven times that of copper.

Let us note here that at present prices iron wire is only five times cheaper than copper of the same size, and therefore copper is the cheaper conductor, as it is seven times more efficient and only five times more expensive. The reason why it is not used for telegraph lines is that it is too soft and would stretch and break if suspended between poles in the usual manner. Wherever, however, this mechanical condition is not controlling, copper is the more economical conductor for electric light circuits.

These relations of resistance to length, diameter, &c., of conductors may be briefly expressed by the following

Sulphuric acid and water, 1 to 11, - - - -	.000,001
Saturated solution sulphate of zinc, - - - -	.000,000,06
Saturated solution of sulphate of zinc, with equal volume of water, - - - - -	.000,000,071
Saturated solution of sulphate of copper, - - - -	.000,000,058
Distilled water, - - - - -	.000,000,000,14
Gutta-percha, - - - - -	.000,000,000,000,000,000,118,8

NOTE.—A small amount of alloy or impurity greatly reduces the conductivity of any metal.

The conductivity may also be expressed inversely or reciprocally by relative resistance, as in the following table :

In this table the numbers express absolute units or thousand millionths of an ohm of resistance for each cubic centimetre of the substance.

Silver, - - - - -	1.609
Copper, - - - - -	1.642
Gold, - - - - -	2.154
Iron (soft) - - - - -	9.827
Lead, - - - - -	19.847
German silver, - - - - -	21.170
Mercury, - - - - -	96.146
Selenium (annealed), - - - - -	6×10^{13}
Sulphuric acid and water 1-2 - - - -	$.196 \times 10^{10}$
“ “ “ 1-11 - - - -	$.332 \times 10^{10}$
Pure water, - - - - -	7.18×10^{10}
Glass (at 200°C.), - - - - -	2.27×10^{16}
Gutta-percha (at 20°C.) - - - - -	3.5×10^{23}

Where numbers reach such magnitudes that it is inconvenient to write them in the usual way, it is customary to express them as above by an “index notation,” in which the number 10 with its index

means that as many cyphers are to follow the other number as there are units in the index. Thus 6×10^{18} means 60,000,000,000,000; $.126 \times 10^7$ means .126 followed by 7 cyphers, because the .126 is a decimal fraction of three places. What such quantities mean may be illustrated by a few examples. The present national debt of the United States is about \$1,600,000,000, would be written 16×10^8 .

The velocity of light, 200,000 miles per second, would be written 2×10^5 .

The total number of atoms in the universe as computed recently is less than 7×10^{91} .

In the case of metallic bodies the resistance is increased by a rise in the temperature, but with carbon, boron and silicon and probably some others, and also in the case of liquids and solutions the reverse is the case. German silver is much less effected by changes of temperature than other metals or alloys, and is thus especially desirable for use in constructing standards of resistance.

To express the resistance of conductors, units have been adopted of which that most commonly employed is called an Ohm, from the name of a distinguished German electrician. This is in a certain sense an arbitrary quantity, although it is intended that it shall have certain simple relations to what are called "absolute units," which are all deduced from the velocity which gravity gives to a body near the earth surface, in one second. To correct the measure known as an ohm in the above relation, the International Congress has decided upon a fresh evaluation, in which the value of the ohm shall be expressed in the length of a column of mercury, one millimeter in cross section. This length will be between 104.5 and 105 centimetres. This will then represent 10^9 . (ten to the ninth power times), the absolute electro-magnetic unit. Lord Rayleigh has recently shown that the

present value of the ohm is only 0.9895 of this quantity, about 1 per cent. out.

As a rough familiar example of what an ohm is, we may say that it is the resistance offered by a copper wire one sixteenth of an inch (1-16) in diameter, and 378 feet long.

Returning to our illustration of the pump with its system of pipe circuits, we may notice in the next place that

Second.—The amount of water flowing through any circuit, or through all the circuits, will vary with the force or pressure developed by the pump. If the pump moves with greater force, producing a greater pressure on the water in front of it, the water will flow faster, more will pass in a given time through each circuit, or the current will be greater. On account of the inertia of the water the increase of current will vary with the square root of the pressure, but in the case of electricity, which is without inertia, it will vary directly with the pressure. In other words, in the case of electricity we may regard the electro-motor (*i. e.* dynamo-machine, battery, or the like) as producing a certain pressure similar to the head or height, of a column of water in a “stand pipe” connected with a pump; and we may then look upon the flow of electricity in the connected circuits as caused by this head or height and directly proportional to it. In this case, of course, we assume that the pump (or electro-motor) takes up the return flow of fluid from its exhaust side just as fast as it arrives, so as to produce neither vacuum nor back pressure.

Under these conditions the height or head of the fluid would be what we call “potential,” and the tendency to flow produced thereby would be what we call “electro-motive force.” It is thus manifest that these two terms are in most cases equivalent, though expressing different ideas.

To express numerically, relative values of "electro-motive force," (often for brevity written E. M. F.) we have the unit known as a *volt*.

This is intended to equal 10^8 (or ten to the eighth power) times the absolute electro-magnetic unit.

To give a general idea of this quantity, we may say that it is just about the electro-motive force of a single Daniell's cell, that being given as from .978 to 1.079 of a volt.

In other words, one volt is a pushing power to set an electric current in motion, such as a single Daniell's cell possesses, which is not enough to decompose water, but which will decompose a solution of sulphate of copper and the like.

For further rough illustration we may mention that to maintain a single good arc electric light, the E. M. F. should be between 25 and 50 volts.

A six light Brush dynamo machine, when making 900 revolutions per minute, develops an electro-motive force of 275 volts.

A sixteen light Brush machine, making 800 revolutions per minute, develops an E. M. F. of 775 volts.

A forty light Brush machine, making 700 revolutions per minute, develops an E. M. F. of 1,850 volts.

It may also be of interest to give here the E. M. F. of some well known forms of galvanic battery :

NAME OF BATTERY.	E. M. F.
Smee, - - - - -	0.65 Volts.
Poggendorf, "Electro-poion," one fluid,	1.75 - 2.3
Daniell, - - - - -	0.978-1.078
Grove, - - - - -	1.78 - 1.956
Bunsen, - - - - -	1.75 - 1.964
Leclanché, - - - - -	1.48 - 1.61
Latimer Clark, - - - - -	1.457
Secondary battery of Planté, Faure, &c.,	2.38 - 2.72

Returning yet again to our illustration of the pump and circuit of pipes, we will see that the current or amount of fluid flowing in any circuit will be increased with the (electro-motive force) "head" or pressure, and decreased in proportion to the resistance, and that it will therefore be expressed by saying that it is equal to the electro-motive force divided by the resistance. This is in fact the famous "Ohm's Law," so frequently referred to and expressed by the equation $C = \frac{E}{R}$. C standing for current, E for electro-motive force in volts, and R for resistance in ohms.

We require, however, a unit in which to express these quantities of current, and this we have in what was formerly called a "Weber" or Weber per second, and is now often called an "Ampère." Just what this indicates we may easily understand by reference to our hydraulic illustration.

If we wished to express the current of water passing in any of the pipes, we could manifestly do so by stating it as so many gallons per second or so many cubic feet per second. Now the Weber expressed a quantity of electricity analogous to a gallon or to a cubic foot of water. The capacity to contain this is and was called a Farad; and the quantity, so contained, it is now proposed to call a Coulomb. This is analogous to a gallon measure and a gallon of liquid.

Now, a current in which a quantity of electricity, expressed by a Farad, a Coulomb or a Weber in motion, passes a given point each second, is called a "Weber per second," or now an "Ampère" current, or current of one Ampère, very much as we would say that a current of water in which one gallon flowed past a given point each second, was a gallon per second or a gallon current.

The direct measurement of currents of electricity is now generally made by allowing them to flow between two copper plates in a solution of sulphate of copper. Under these conditions, cop-

per is taken from one plate and deposited upon the other, and the gain in weight of the negative plate shows the strength of current, as it has been proved that a current of one Ampère will deposit 0.000,326 grammes of copper per second, and to deposit one gramme of copper would require 3,062 Webers of electricity; or, again, a current of one Ampère would deposit 1.1736 grammes, or less than $1\frac{1}{8}$ grammes in an hour.

Though not, perhaps, essential in the present connection, it will be well to give here the relation of current to work, as this will afford a means occasionally of testing the claims made in behalf of certain machines, or statements as to the currents actually in use.

The law first announced by Joule, as to the relation of work to current, is this

Joule's Law.

Current squared, multiplied by resistance, multiplied by time, equals work of current—or, as an equation, $W = C^2 \times R \times t$. Experiment has moreover demonstrated (what may also be deduced from general principles) that a current of one Ampère through a resistance of one ohm, develops in one minute a work equal to 44.24 foot-pounds. Suppose, then, that we have a current of 10 Ampères overcoming a resistance of $3\frac{1}{2}$ ohms, this would represent in each minute, $10^2 \times 3\frac{1}{2} \times 44.24 = 15,484$ foot-pounds, or less than half a horse-power, which is 33,000 foot-pounds per minute.

The above numbers of Ampères of current and ohms of resistance are about those found in an average Brush arc light, and show us that if no loss whatever occurred in any part of the apparatus, such a light might be maintained with less than half a horse-power. In practice it requires nearly twice as much; but

it is interesting to notice that the above is a limit which cannot be exceeded, even with apparatus theoretically perfect.

The current used in an ordinary incandescent lamp is often about $\frac{7.3}{100}$ Ampère, and the resistance is about 137 ohms when in use—this gives us $.73^2 \times 44.24 = 3,230$ foot-pounds per minute, or almost exactly one-tenth of a horse-power.

This also is a limiting quantity which can never be exceeded, under the conditions here assumed, and in practice is only so far approached as to make such a lamp of 16 candle power require one-sixth of a horse-power.

HENRY MORTON, PH. D.

UNDERWRITERS' STANDARDS.

CAPACITY OF CONDUCTORS.

FOR ARC LIGHTS.—The standard in this connection is expressed as follows:

“The conductor must have a weight per running foot at least equal to that of the wire, or parallel group of wires, constituting the main circuit of the magnetic regulator of the electric lamps, or of the armature of the machine employed, whichever of these is the largest.”

In making an inspection in reference to this rule the following plan may be adopted:

In the first place it should be remarked, that weight per running foot is in this case synonymous with size where the ordinary solid round wires are used. If, however, hollow conductors or flat strips are employed, regard must be had, not to their surface or exterior size, but to their area of cross section, which is, of course, directly proportional to, and frequently most easily determined by, their weight per running foot.

A failure to fulfill the requirements of the above rule in any considerable length of line wire would involve so serious a loss in economy, that it is not at all likely that an inspector will encounter any case of its violation, except in some short piece of wire inserted in a circuit otherwise more than fulfilling the requirements.

He should, therefore, first carefully inspect the entire line, and see that it is all of about the same size of solid conductor. If any piece of smaller conductor is observed to be inserted anywhere, this should be closely examined, and compared with the wires of the lamps and armatures as directed. As a rule all such reduction of size in a line conductor should be discouraged.

In applying the conditions of the rule, the inspector will examine the lamps used, and notice the size of the wire in their "main circuit."

By this it is intended to distinguish the main circuit of the lamp through which most of the current flows from the "shunt circuit," carrying only a fraction of the current for purposes of regulation. This last circuit is generally made of very fine wire and can thus be distinguished. It will in fact be sufficient for the inspector to compare the line wire as to its size with the largest wire he finds in the coils of the electric lamps.

A similar rule applies to the armature of the machine. If this is wound with wires of unequal thickness, which may be the case though it is not usual, the thickest or heaviest wire should be selected as the standard of comparison.

It is of course possible, both in the lamp and machine, to use several parallel circuits of fine wire in place of one of thick wire. In this case of course the aggregate cross section or weight per foot of the small wires must be taken as the standard.

The fact that such parallel circuits are in use must be determined by a careful examination of the apparatus in question, bearing in mind that wherever any number of conducting circuits are in connection with two points on an electric circuit the current will divide itself between them in proportion to their conducting power, or in other words, inversely as their resistance.

Arc lights are always operated in successive series, that is to say, the circuit runs in succession through one lamp after another, and therefore it is manifest that a conductor, whose capacity is sufficient for one light, will be sufficient for any number in succession. The only difference is in the electro-motive force or head of the current. Thus a single Brush light will require a current of about 10 Ampères quantity and about 47 volts E. M. F., and if we wish to operate 40 such lights we will require a current of only 10 Ampères quantity likewise, but it must have an E. M. F. of about 1,880 volts. This therefore calls for no variation in the size of the conductor between circuits of one and of forty lights, but it makes a great difference as to the care required in securing insulation, as we shall see further on.

In the system of the United States Electric Company the current usually employed in arc lights is of about 16 Ampères quantity and about 25 volts E. M. F. for each lamp, or 250 volts for a 10 light machine.

For the same number of lamps in series, therefore somewhat heavier conductors should be employed, but the insulation need not be so great.

CAPACITY OF CONDUCTORS FOR INCANDESCENT LIGHTS.

In the case of incandescent lights, which are operated *not in successive series* but in parallel circuits and where also the machines have conductors of immense size on their armatures, it would be impossible to secure safety by following the rule laid down for the arc lights. A different method has therefore been adopted in this case, that namely of introducing "safety-catches" at numerous points.

The rule is expressed as follows :

"Wherever a connection is made between a larger and a smaller conductor at the entrance to or within a building, some approved automatic device must be introduced in the circuit of the smaller conductor whereby it shall be interrupted whenever the current passing through it is in excess of its safe carrying capacity."

CAUTION.

"The safe carrying capacity of a wire is that current which it will convey without becoming painfully warm when grasped in the closed hand."

In reference to this it must be remembered that this test cannot safely be made with the wires carrying currents for arc lights, and it is intended to be applied only with reference to the conductors of incandescent lights. These may be handled without risk ; but with the conductors of the arc lights, where, as is usually the case, there are a number in series, a severe shock may be experienced on touching the wire, and if a ground connection existed by chance elsewhere, and some other conditions were present by which the full force of the current passed through the body, this shock might be fatal.

It is an excellent rule, in handling in any way, any apparatus carrying these currents of high electro-motive force, to place one hand in the pocket, so as to avoid the risk of completing a circuit through the body, by grasping two parts at once with the two hands.

Whenever any work is to be done on arc light circuits requiring the use of both hands, the current should always be cut off beforehand.

Several forms of safety-catch have been already devised, and many others will no doubt be introduced from time to time, and if shown to be reliable will be approved in due form by the New York Board of Fire Underwriters.

The following have been approved already :

THE EDISON SAFETY CATCH.

This very efficient device is shown in Fig. 7, as seen from above, with the plugs taken out and placed one, upside down, and the other straight, beside it.

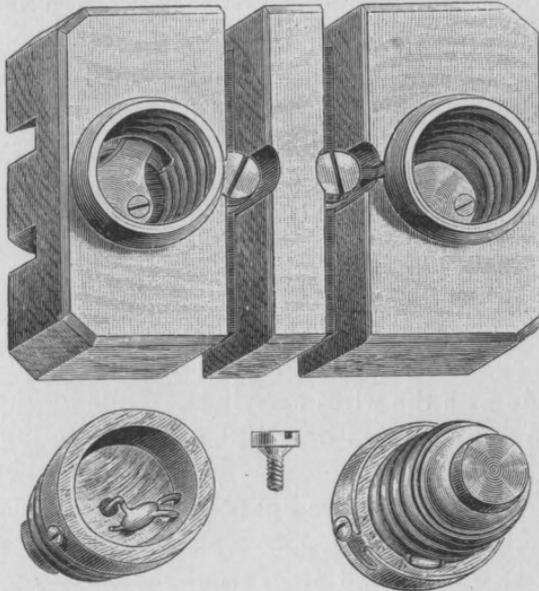


Fig. 7.

It consists of a block of hard wood, with certain grooves and holes cut in it as indicated.

The two large holes have screw threads cut in them, and these are lined, as it were, with cylinders of brass moulded to fit the said screw threads, thus giving us hollow screws lined to a certain depth with metal. These metal linings are put in connection with the main conductors by means of the binding screws running into the transverse slots or grooves across the block through which the main conductors pass.

As a consequence, it is manifest that the metal lining of one hollow screw, is connected with the incoming, and the other with the outgoing main.

At the bottom of each of these hollow screws is a piece of metal insulated from the metallic lining of the screw hole, and so arranged as to be connected with the branch circuit.

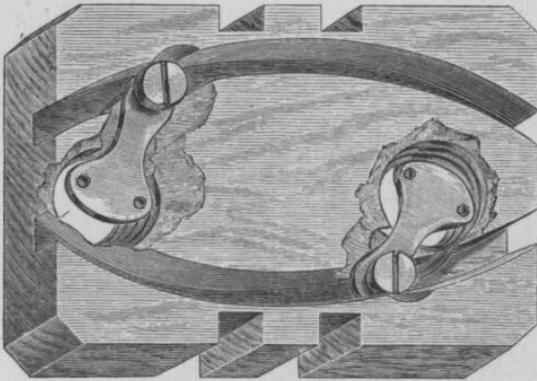


Fig. 8.

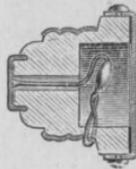


Fig. 8a.

This is made clear by Fig. 8, which is a view of the same safety catch turned over.

Here we see the bottoms of the screw holes with the metal plates in them, whose outer ends are connected by binding screws with the branch wires which run in the curved grooves. Clearly,

then, a path would be supplied from the main to the branch circuit, if the linings of these hollow screws were connected with the plates at their bottoms.

This connection is furnished by plugs, one of which is shown in section at the lower part of Fig. 8a.

This is a screw fitting into the hollow screw holes of the block already mentioned. It has a metallic casing on its upper portion, which, when it is in place, makes connection with the main circuit through the lining of the screw hole, and it has a metallic cap on its point which connects with the branch circuit through the plate at the bottom of the screw hole, and this casing and cap are connected in the plug by means of a wire of lead alloy, contained in the interior of the plug, as shown in the section.

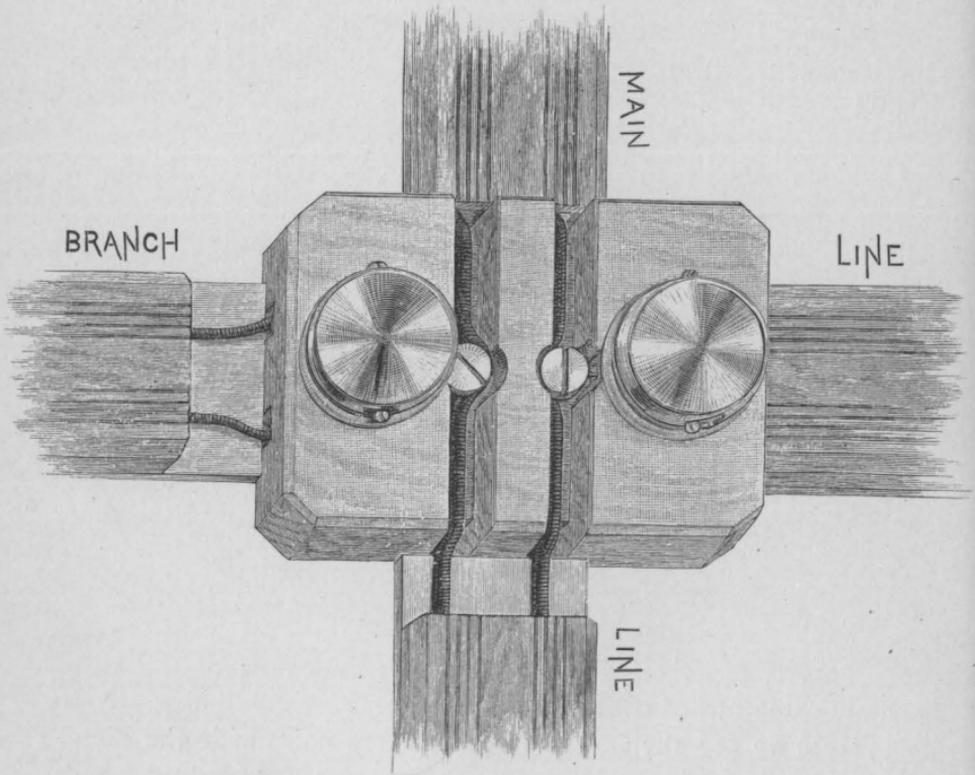


Fig. 9.

Should the current passing through this lead wire become greater than it is intended to convey, it will melt and so interrupt the circuit.

To restore the circuit, it is only necessary to replace the plug by a new one.

The size of the lead wire in the plug must, of course, be proportioned to the amount of current which it is intended to transmit.

It will be observed that the safety catch above described is double, or capable of making two breaks in the one circuit; this, of course, gives double security, and also affords an easy means of cutting off the branch circuit and testing its insulation.

The appearance of this safety catch when everything is in place, and one of the methods of laying the wires connected with it, is shown in Fig. 9.

The upper ends of the plugs are covered by brass caps, and these caps can be removed, and the condition of the fusible wire ascertained, without the removal of the plug or the breaking of the connection. The wires outside of the block are run in grooves covered by flat strips of mouldings.

The mouldings to the left and under side of the cut are shown as drawn away, so as to expose the wire.

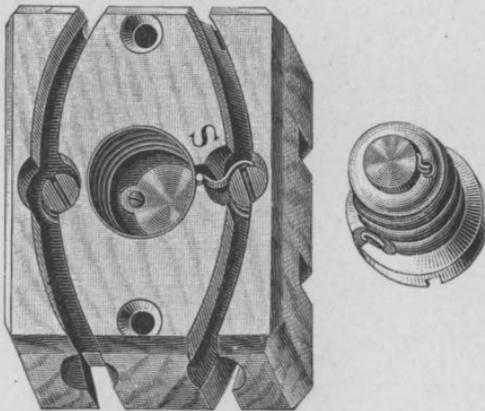


Fig. 9a.

In many cases it is unnecessary to introduce the fusible connection in both the outgoing and return lines of the branch; and in this case the arrangement shown in Fig. 9a, is employed, which

is exactly like that already described, except that there is only one safety plug which is introduced on one of the branch line wires. In all ordinary cases, the single plug safety catch is sufficient for safety, and the double plug need only be insisted upon where there are special risks of contact with wires or other conductors having ground connections.

THE U. S. CO. SAFETY CATCH.

This apparatus shown in the adjacent wood-cut consists of a thin strip of easily fusible alloy held between two metal clamps, and thus forming part of the circuit.

When the current which passes through it becomes too great, the fusible strip is melted and interrupts the circuit.

For heavier currents the form of this apparatus is modified as shown in Figs. 11 and 12, Fig. 11 showing the inside and Fig. 12 the outside, or cover.

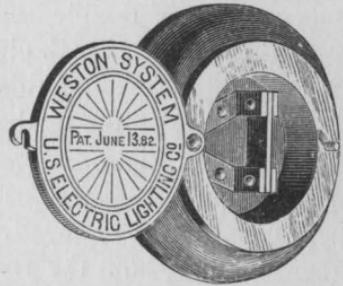


Fig. 10.

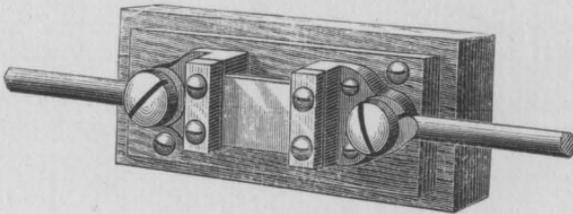


Fig. 11.



Fig. 12.

The alloy used in these catches fuses at so low a temperature that no risk of fire exists from the fused material.

INSULATION.

In reference to insulation, it is to be noticed that under no conditions likely to be met with in electric lighting, can the electric current simply escape or pass out from a conductor. What we have to guard against, is the completion of a circuit, by means of a chain of conductors more or less perfect, between the positive and negative poles of the machine or electric generator. Here, however, we must remember that the earth at large is a good conductor, and that all systems of gas, water and steam pipes, passing through buildings, are almost certainly in thorough connection with the earth and with each other. Iron buildings, or iron parts of buildings, are also likely to be in connection with the earth, and thus all these may form parts of a circuit, if they come in contact with the conducting wire, and are otherwise connected with the machine or other part of the circuit.

To reduce the risk of forming such circuits to a minimum, it is in the first place required that "All wires, machines and lamps are to be so mounted and secured as to insure complete and continuous insulation." It is, moreover, further stated, "In no case must 'ground circuits' be employed, or any portion of the system be allowed to come into conducting connection with the earth, through water or gas pipes, or otherwise."

The reason of this is obvious. If the earth or any earth-connected system, such as water or gas pipes, is used as part of the circuit, then a single contact of one of the conductors with any other pipe or other earth-connected conductor, would complete a circuit, with the risk of disastrous consequences. If, on the other hand, the entire system is insulated, then such a single contact would be relatively harmless, and two contacts at distant parts of the circuit would be needed to produce disastrous results. The insulation of the *entire system* thus doubles the security.

The inspector should therefore see that in all cases the dynamo machine is mounted on a base of wood, with no metallic

connections between its frame and the floor, or masonry foundation on which it may rest. Of course a wooden floor, if dry and clean, would form a sufficient insulation; but on account of the liability which exists that a floor may become wet or covered with metallic dust, it is not desirable to trust to it alone for insulation of the machine.

It is mainly on account of this risk of establishing a connection by means of water, that it is unsafe to carry conductors along on wooden partitions, ceilings or the like, without thorough insulation of the wire and its means of attachment.

Two parallel wires, one being the outgoing and the other the return line of an arc-light circuit, would be entirely safe if nailed or stapled six inches apart on a dry board, with no insulation but the wood. If, however, a little water were spilled on the wood, a circuit would be established which would heat the water and wood, more and more, until the surface of the latter was charred, thereby becoming a good conductor, with minute arcs forming where its surface cracked. These, in turn, would soon develop a vigorous combustion.

To produce these effects, it is necessary that a current of high electro-motive force, such as that developed by the larger arc-light machines, should be employed; but its existence indicates the necessity of such precautions as the Board has directed in all cases, since other possible conditions, such as the presence of metallic filings or dust, would extend this action to feebler currents.

INSULATION OF THE MACHINE.

The inspector should therefore see that the dynamo machine, in any plant, is insulated as regards its base, and so protected that accidental connection between it and the earth may be avoided, by the use of a railing, screen or the like.

The mounting shown in the accompanying drawing is a very satisfactory one. It not only secures the thorough insulation of the machine but also renders it easy to adjust the tightness of the belt which drives it. By reason of its elevation above the ground,

it greatly reduces the chance of accidental connection from any cause, and indeed may be considered as fulfilling the requirements in this connection in the most perfect manner possible.

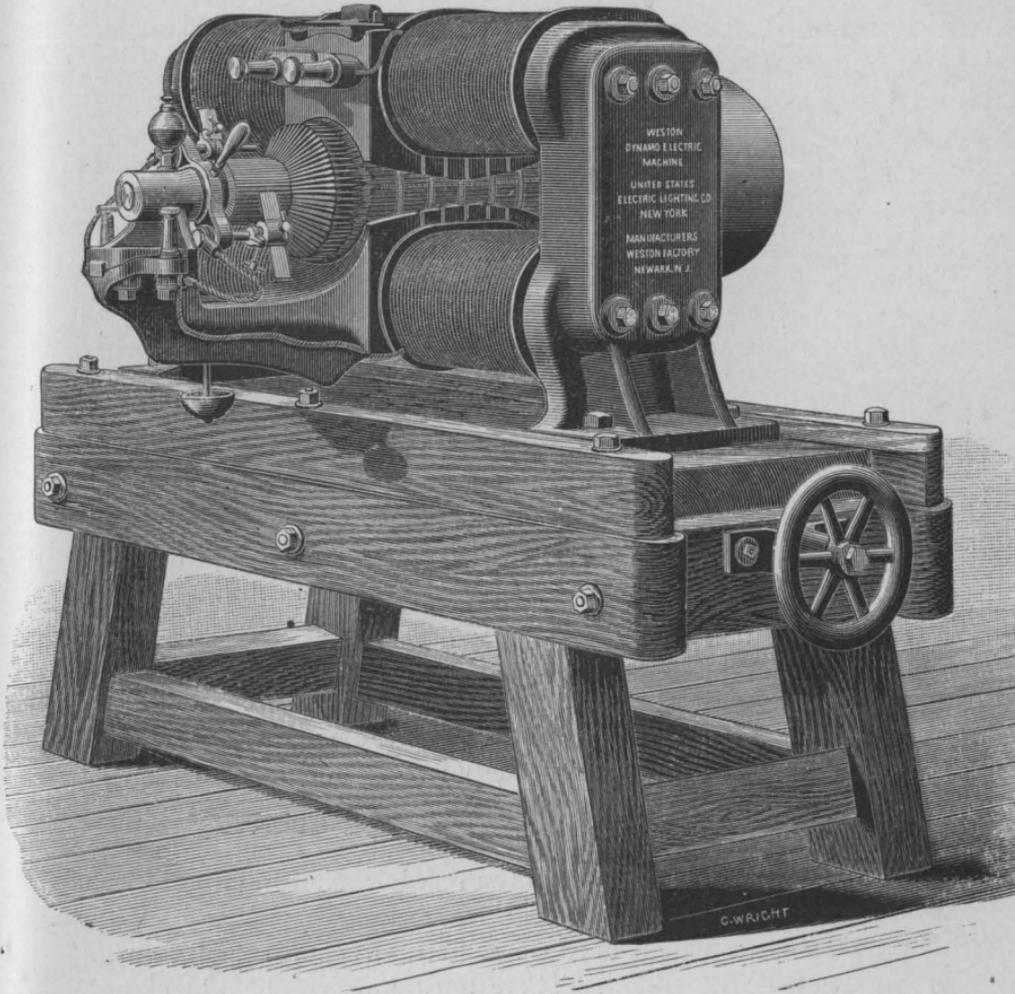


Fig. 13.

WESTON DYNAMO-ELECTRIC MACHINE--AS USED BY THE U. S. ELEC. Co.

Such a mounting as is shown in the accompanying Fig. 14 is not to be recommended, and indeed cannot be admitted where

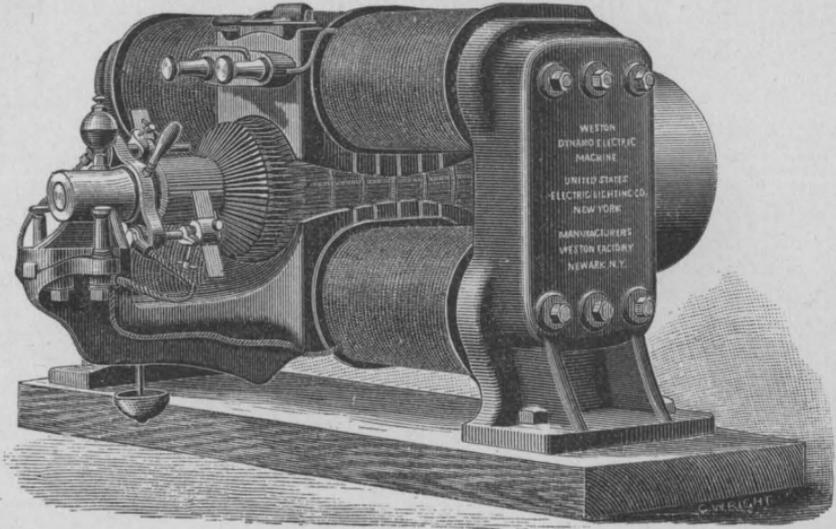


Fig. 14.

WESTON MACHINE.

the machines are used for arc lights, except where all chance of connection, through a wet floor or the like, is otherwise provided against. For incandescent lights it is admissible if the bolts connecting the machine to the wooden base do not run through, and the locality is an essentially dry one.

INSULATION OF THE EDISON MACHINE.

This machine is so heavy that no bolts are needed to secure it to the floor, and thus it may be safely insulated, in dry locations, in the manner shown in the accompanying drawing, Fig. 15.

The machine shown in outline is of metal, but the block below is of wood, and this, together with the very low electro-motive force of these machines, 110 volts, will suffice to secure their insulation, unless where much moisture is present, when some special protection must be added. There must, however, be a block of insulating material between the point of the adjusting screw and the iron base, as otherwise a ground connection might be made by leaving in, the bar used to turn the adjusting screw. The inspector must also see that the tracks on which the machine rests

are not fastened to the wooden base by screws or bolts liable to make a ground connection.

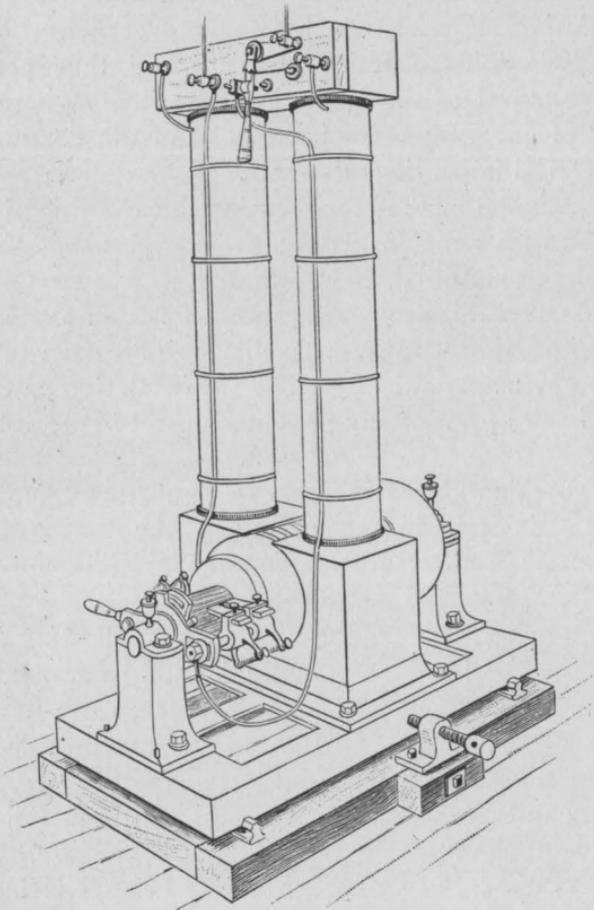


Fig. 15.

When, as is sometimes the case in other systems, two or more machines are coupled in series, then the degree of insulation throughout all their connections must be arranged with reference to this increase of electro-motive force.

Having seen to the proper insulation of the dynamo machine, the inspector should next turn his attention to the line wires. These should be two in number, one for the outgoing, and one for the return current.

They should be coated with insulating material throughout, and this material should combine mechanical with electrical protection. In other words, there should be in addition to the coating of insulating material, which is to prevent electric contact, some covering able to resist abrasion and thus prevent the accidental removal of the insulating covering. Wherever there is any risk of exposure to moisture, one of the coatings should be of a material impervious to water.

A very common method for securing this condition is to cover the wire first with some insulating compound like "Kerite," or Gutta-percha or cotton thread saturated with a tarry substance, and then to cover this again with a woven fabric, alone, or itself saturated with paint, varnish or the like. This outer or mechanical armor may be metallic, provided the insulation on the wire is so arranged as to prevent any possible contact between it and the conductor.

Such a combination, satisfactory in its character, is seen in the conducting mains laid in the streets by the Edison Company, where the outgoing and return conductors are rigidly supported side by side in iron pipes, the space between the two conductors and around them being filled with a tarry compound—fluid when hot.

Also in the small conductors used by the same company for branch lines in buildings, which consist of copper wires covered with woven fabric, saturated with a non-conducting mixture, inclosed in small pipes of zinc.

Outgoing and return, or positive and negative wires, however, should not be inclosed in the same tube in this case. In chandeliers it is allowed, but only when a safety-catch is inserted at the base of the chandelier, or special precautions are taken to secure the rigid attachment and permanent insulation of the wires.

It would even seem to be entirely admissible where incandescent lights only are concerned, and the currents used are of low electro-motive force, to employ small leading wires covered with cotton saturated with some waterproof insulating non-inflammable substance, and laid in grooves of wood, afterwards filled with a tarry insulating substance, fluid when hot, but solid when cold. Positive and negative wires however must not be placed in the same groove, unless such insulating material as this is employed.

Where two or more wires from the same pole of the machine are concerned, in the case of incandescent lights, it is not necessary that they should be kept at $2\frac{1}{2}$ inches distance from each other, provided all chance of direct contact is avoided.

Thus, such wires may be laid as above in the same groove, and out-going and return wires in parallel grooves, $\frac{1}{2}$ inch apart.

The outgoing and return wires for arc lights should, as a rule, be kept eight inches from each other, but an exception to this may be allowed in the immediate vicinity of the lamps where such a separation may in some cases be impossible. In this case, however, special care must be taken to provide against accidental displacement of such conductors.

The same care as to rigid securing in place, must be observed wherever the conductors approach any other wire or conducting body, capable of affording a ground connection, and some solid, continuous non-conducting material, such as dry wood, must be interposed in such cases between the wire and such conductor and rigidly attached to both.

The reason why inflammable material as an insulation to wires is not allowable, is that it forms a train, carrying fire from one point to another in case fire occurs from any cause at one point on the line. The origin of the fire here referred to need not be electric. Cotton-covered wires soaked in paraffine are not admissible for this reason, but the cotton-covering may be soaked in fire-proof paint or the like.

“Wherever wires are carried through walls, floors or partitions in buildings, they must be surrounded by a special insulating tube of substantial material.”

The above condition would be manifestly fulfilled by the use of a porcelain tube, but its intention would also be met by the use of an iron tube with a porcelain lining, or of a hard metal tube much larger than the wire, the space between being packed with insulating material, and caps of insulating material being provided to prevent contact between the wire and the ends of the metallic tube, and wires passing through exterior walls of buildings should be encased in such tube and placed in a manner to prevent rain water from entering the building along the wire; or, in other words, the tube must incline upwards from the exterior,

and the wire, where it passes out of the tube, should be wrapped with insulating tape.

Electric light wires, when carried through streets, should be supported on special polés, and not on those used for telephone or telegraph lines, and should not be supported on houses, as there is a serious risk, in case they get loose, that they will make ground or other dangerous connections.

To add to the safety from this source of danger the daily test for "grounds" mentioned in the "requirements" is insisted upon.

All joints must be made in such a manner as to secure a perfect and durable contact.

No hooking together or other form of connection liable to become loose or imperfect must be allowed.

A good form of connection is that shown in the accompanying cut, Fig. 16.

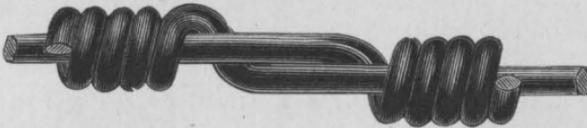


Fig. 16.

No wire should be allowed for arc lights smaller than No. 6 of the American Wire Gauge.

Though it would be desirable to have all electric wires placed under ground, this does not seem possible in the present state of constant change in the localities where the lights are required, but must wait until this business has assumed a more permanent and settled shape.

ARC-LIGHT LAMPS.

The frames of these lamps should be so arranged that their exterior or exposed parts shall not be connected with any portion of the electric circuit, and the light itself must be enclosed in a glass globe closed at the bottom, so that no spark or particle of ignited carbon can fall through, and (where inflammable materials are near the lights) furnished with some spark-arresting device or closure above.

The globe must further be provided with a wire netting to keep the parts of the globe in place in case of its fracture during use.

Excellent examples of lamps thus arranged are furnished by the following patterns :

THE BRUSH LAMP.

In this Lamp, the light is enclosed in a glass globe, with a close-fitting bottom plate, a spark arrester above, and the carbon rod and regulating apparatus are likewise enclosed in metallic cases, all of which, as well as the outer frame, are insulated from the circuit. A stop at the bottom prevents the carbon from falling out, even if the clamp inside does not hold it. This lamp is perfectly satisfactory — even when inflammable material is encountered.

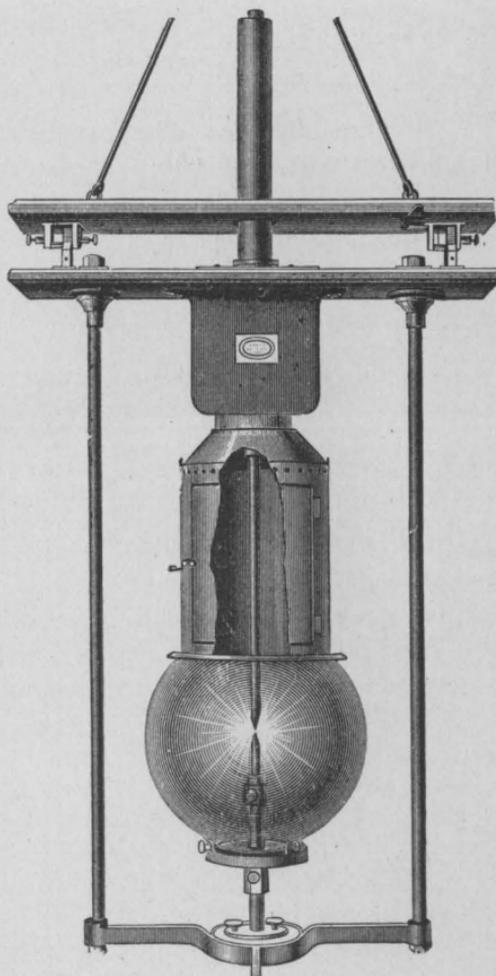


Fig. 17.

BRUSH INSULATED ARC LAMP.

THE WESTON DOUBLE CARBON LAMP.

USED BY THE U. S. ELEC. CO.

In this lamp the leading wires are connected to the ends of the insulated wires seen projecting at A and B of the accompanying figure. These insulated wires carry the current to the regulating mechanism of the lamp, which is all insulated from the inclosing case.

The current is also led to the lower carbon holder by an insulated wire which passes inside of one of the vertical bars supporting the globe, and this carbon holder is likewise insulated from the lower part of the frame.

This lamp may be used where there is no risk of fire from flying dust, but must not be admitted where fire might occur from inflammable material getting into the open end of the globe, unless provided with a spark arrester above the globe.

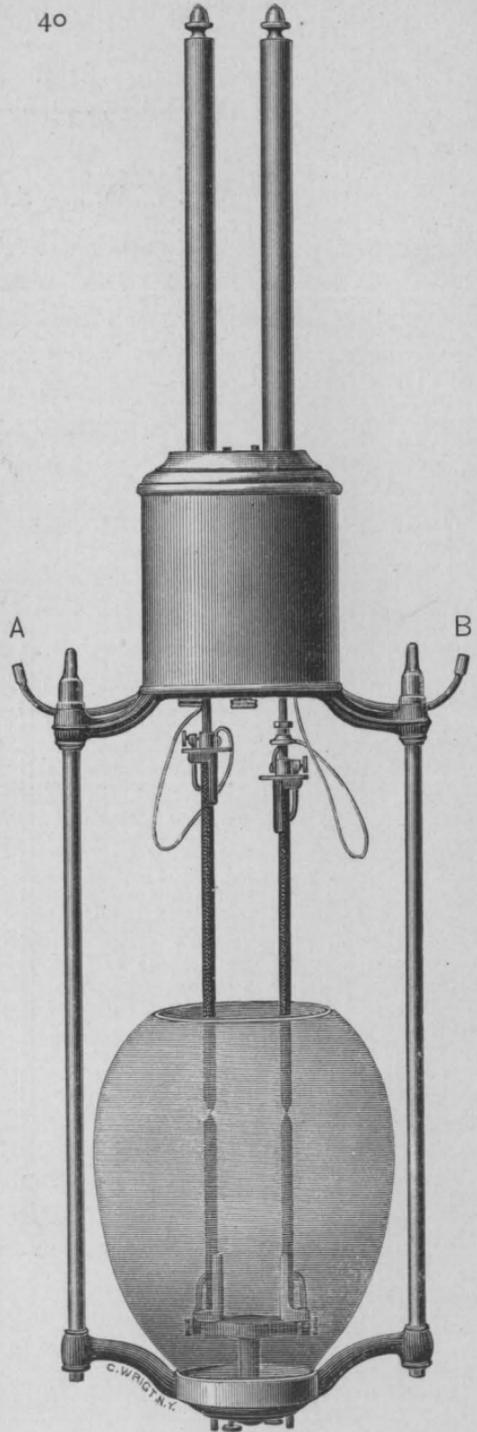


Fig. 18.

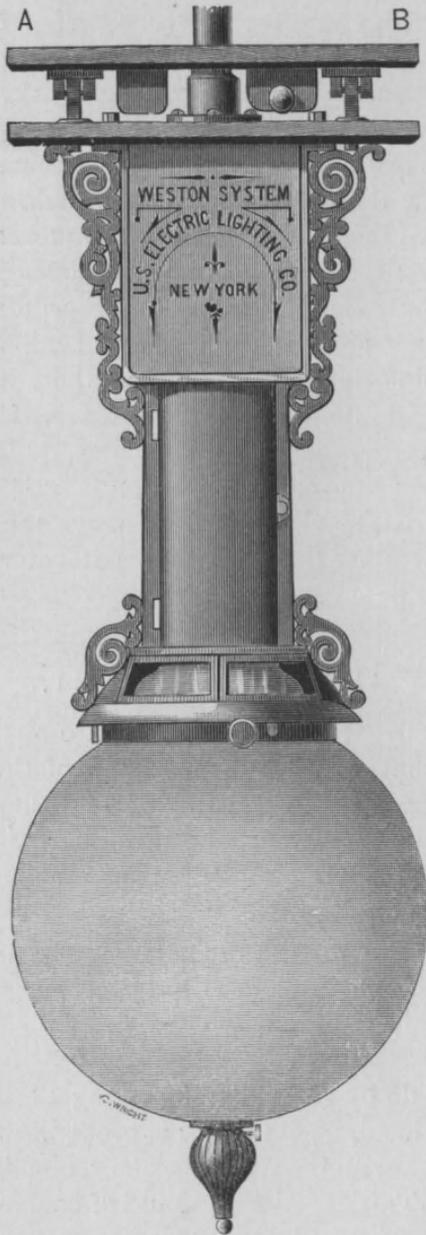


Fig. 19.

A much safer form of lamp is that shown in the accompanying woodcut, Fig. 19, which represents a lamp also used by the U. S. Elec. Co. and designed by Mr. Weston.

Here the current enters by the suspending hooks A and B, and thence traverses the lamp without in any place making contact with any part of the external shell of the lamp.

The whole lamp is moreover inclosed so that no possibility exists of communicating fire to inflammable material outside.

Immediately to the left of B is a hand switch, and an automatic cut-out is inclosed inside, as will be shown presently.

In order to test the insulation of the frames or other exposed parts of one of these electric lamps, the inspector should provide himself with a short piece of small size of flexible insulated wire, and connecting one end to the line wire, where it enters the lamp, bring the other end into momentary contact with various parts of the frame and casing. If he obtains a spark at the rupture of these momentary contacts, the insulation is bad; if he obtains no spark from any part, he should then remove the short wire and reattach it to the other line wire, where it enters the lamp, and repeat the test as before.

AUTOMATIC SHUNT.

Wherever a current of such high electro-motive force is employed, that if concentrated on one lamp of the series it would produce an arc capable of destroying or fusing parts of such lamp, an automatic switch must be introduced in each lamp by which it will be thrown out of circuit before the arc approaches any such dangerous extent.

In determining whether or not this requirement has been fulfilled, the inspector must in the first place satisfy himself, in case no shunt is provided, that the current is not of such a nature as to require one.

This he may do by gradually elongating the arc of one lamp of the series, by hand, until the arc is broken. The character of the elongated arc will then readily show him if it is a safe or dangerous one. This experiment would of course be unnecessary, as well as unsafe, where 16 or more lamps are run in series.

A safe arc is one which does not cause any considerable flame about the upper carbon; whenever in elongating the arc a notable flame or blaze is seen rising above the arc and endangering the

lamp, it is to be considered dangerous. In making this test always keep one hand in the pocket.

In general, any case where more than five arc lamps of about 50 volts each, or 10 of 25 volts, in series are used, it may be assumed that they would not be safe without automatic shunts. Among the various devices for this purpose the following may be noticed.

THE WESTON AUTOMATIC SHUNT FOR ARC LIGHTS.

This arrangement is shown in the accompanying wood-cut, Fig. 20. Two parallel wires, insulated from each other, pass down the vertical tube to the right, and terminate respectively in the insulated jaws of the open spring clip, shown in plan immediately below. This spring clip is kept open by a band of fusible metal on its left side, which is near to and above the arc. If the arc is excessive, its heat will readily melt the fusible strip, so allowing the opposite jaws to come together, and thus close a connection between two vertical wires, which are connected respectively with the incoming and outgoing leaders. The current will then be shunted through this path of low resistance, and thus leave the arc.

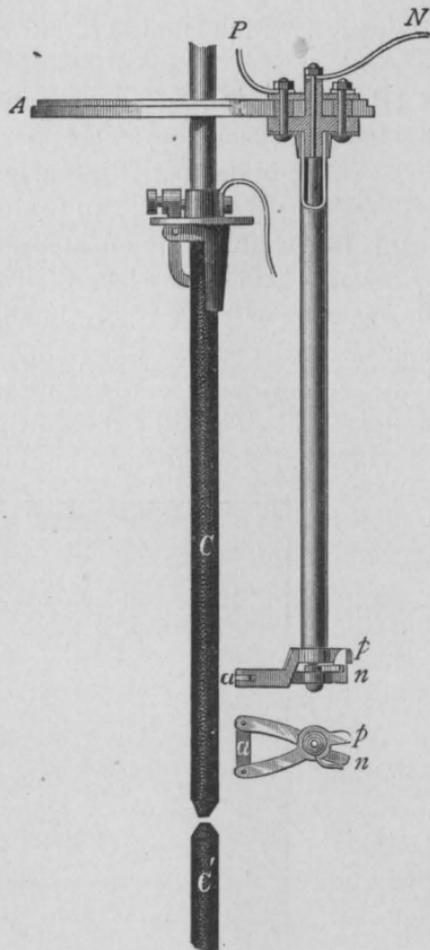


Fig. 20.

THE BRUSH AUTOMATIC SHUNT FOR ARC LAMPS.

“Fig. 21 is a diagrammatic sketch, showing the course of the primary circuit, and illustrating the general principle by which the arc is controlled; it also shows the short circuiting contrivance by which any accident to one lamp, or irregularity of working, cuts it out of the general circuit, and does so without exercising any influence upon the other lamps in the series. In this diagram, X and Y represent the two terminals of the lamp, which in most cases consist of hooks, which, by being dropped over pins attached to the ceiling—and which are in connection with the line circuit—place the lamp in circuit with the machine. The current, entering at X, is transmitted through the two hollow bobbins, H H', in parallel circuit, the outgoing ends being joined together and connected to the upper carbon holder, N; and if the carbons are in contact, the current flows through them, and by the vertical rods of the lamp to the terminal hook, Y. The effect of this is to convert the solenoids, H and H', into magnets; which, by drawing into themselves the two iron plungers, shown within, lift one edge of the washer clutch, W; which, by its oblique action, seizes the carbon rod (much in the same way as a tent-rope tightener grasps its cord), and lifts the upper carbon until its influence is balanced by that of the fine wire helix, which, it must be remembered, surrounds the thicker coil.

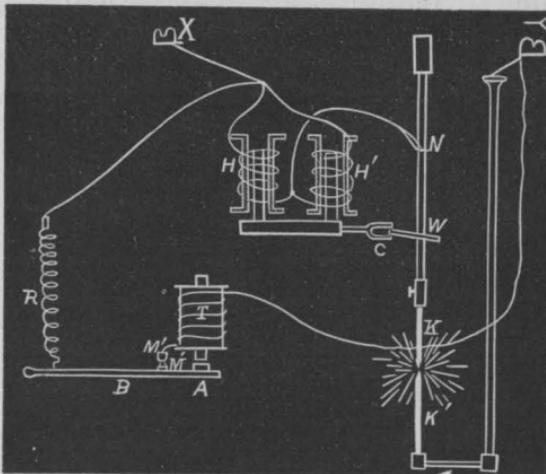


Fig. 21.

“The short circuiting apparatus shown to the left of the carbons (see Fig. 21), consists of an electro-magnet, T, wound with a thick and fine wire coil similar to those of the regulating solenoids, but both wound in the same direction. When the thick wire circuit of this magnet is complete, it forms a shunt of low resistance between the terminals, and therefore short-circuits the lamp, transmitting the current to the main circuit. Now the fine wire wound upon this magnet is in circuit with the fine wire of the regulating solenoids; it follows, therefore, that if through a failure of the arc, or through its becoming abnormally long, or through any considerable increase in its resistance, a larger proportion of current be diverted through the fine wire circuit, the attractive force of the electro-magnet, T, would be increased, and its armature, A, which is attached to the pivoted lever, B, would be at-

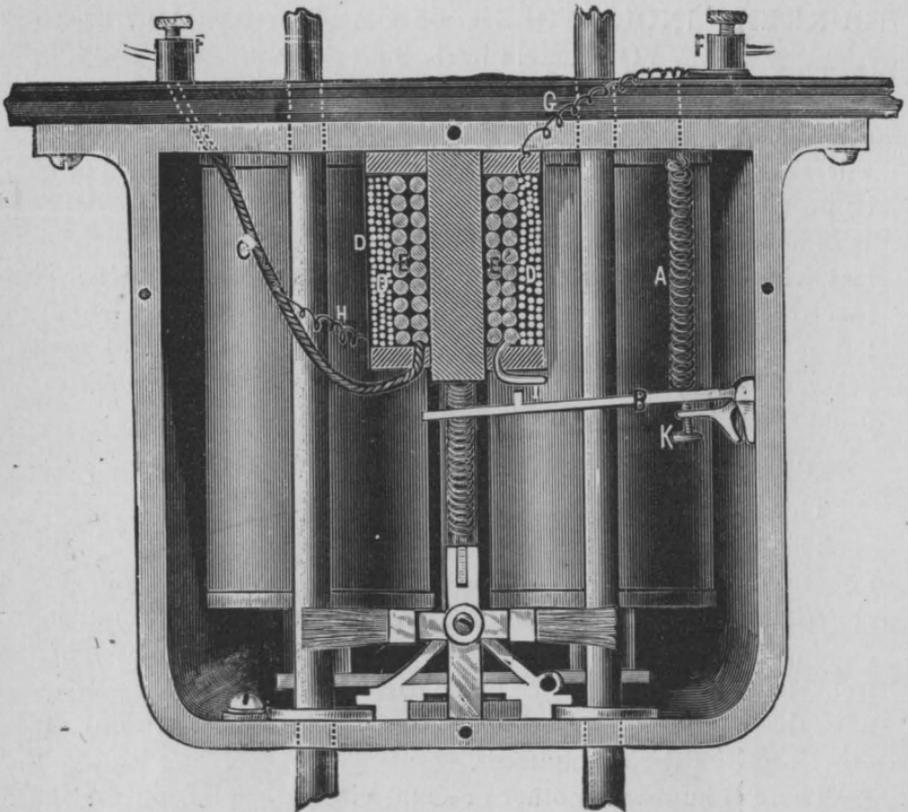


Fig. 21a.

tracted; the contact pieces, M and M¹, would thereby be brought together, and the terminals would be short-circuited through the thick coil, M, and the resistance spring, R. By thus short-circuiting the terminals, through a route altogether independent of either the fine or the thick wire solenoids, their magnetic action ceases, and either the upper carbon is dropped, or if it is burned out, or from any other cause the arc is not established, the contact pieces, M and M¹, are held firmly together by the attraction of the magnet, T, and the current flows past the faulty lamp to the others in the series, its extinction calling attention to it."

The above description is copied from the *Brush Electric Light*, of March, 1882.

The preceding cut, Fig. 21a, shows the details of this automatic shunt, as actually constructed in a two-carbon Brush lamp.

CURRENT INDICATORS OR CURRENT REGULATORS FOR CENTRAL STATIONS.

Means by which those in charge of the dynamo-electric machines will be warned of any excessive flow of current, or means whereby the same will be automatically checked, must in all cases be provided.

The safety of the dynamo machines and avoidance of loss will, without doubt, induce all those furnishing electricity to use such indicators or regulators as are referred to above, but it will be well for the inspector to assure himself of their presence, and we therefore give here descriptions of the most usual forms.

BRUSH AUTOMATIC CURRENT REGULATOR.

This apparatus is arranged in the following manner:

The magnets which supply the magnetic field in which the armature rotates, in other words the large magnets of the dynamo electric machine, are connected directly in the main circuit, including the lights and line generally, so that the current taken from the commutator by one brush passes round these electro magnets, thence to the line and lights, and by the return wire to the other brush of the commutator.

There is however another or shunt circuit which connects the first brush with the line so as to skip over the electro magnets,

and thus allow any current flowing in it to pass out from one brush into the line and back to the other brush without going through the electro magnets of the machine. This shunt circuit goes through a resistance box made of carbon disks, pressed together by an electro magnet, operated primarily by the main circuit. When the current in the main circuit increases for any cause, as by the shutting off of some of the lamps, a cross connection or the like, the magnet brings greater pressure on the carbon disks, thereby diminishing their resistance and thus allowing a greater part of the current to flow through the shunt circuit and not through the field magnets of the machine.

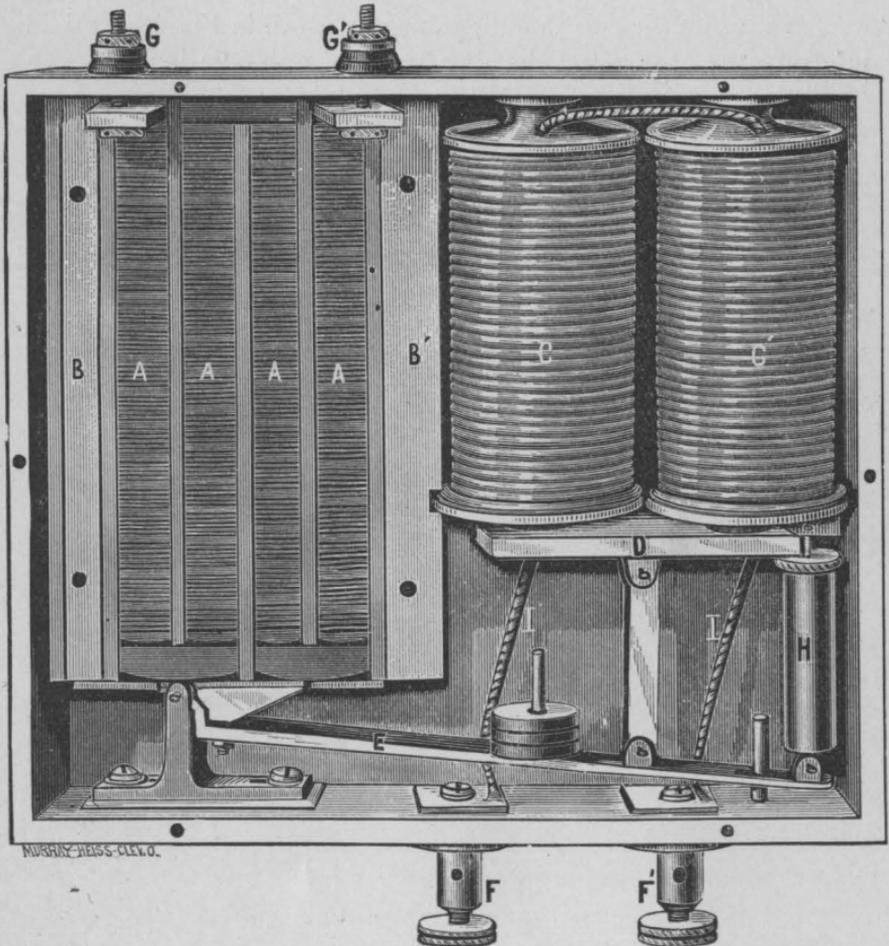


Fig. 216.

This of course diminishes the magnetic force of these field magnets and therefore reduces the current produced in the armature rotating in their field.

To increase the sensitiveness of this governor, the shunt circuit is also carried round the magnet which causes pressure on the carbon disks, thereby aiding the main current in modifying their resistance.

The accompanying cut, Fig. 21*b*, shows the arrangement of of the electro-magnet and carbon resistance box, constituting the shunt circuit above described.

WESTON CURRENT INDICATOR.

An exterior view of this instrument is given in Fig. 22, and an interior view or diagram showing its mode of operation is given in Fig. 23.

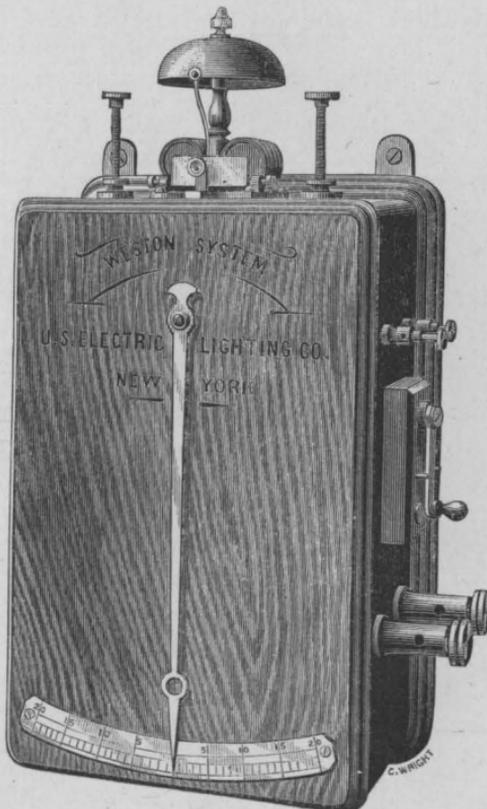


Fig. 22.

The operation in this device is as follows :

A branch from the main circuit communicates by means of the lower binding posts on the side of the box with the inclined electro magnet near the top of the box and draws the Z shaped armature around so as to deflect the pointer connected with it to the right.

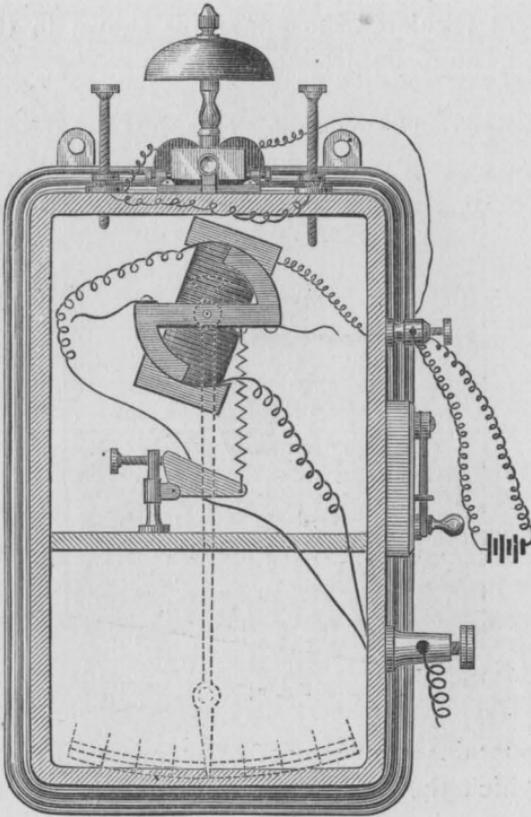


Fig. 23.

By means of the adjustable spring in the middle of the box this displacement of the pointer is overcome, until with a normal current it stands at the middle of the scale. An increase of current then moves the pointer to the right and a decrease to the left.

A small battery placed inside the box, but shown in the diagram, Fig. 23, as outside on the right, is connected with the Z shaped armature on one side, and on the other through the bell to the long vertical screws which pass through the top of the box.

When the armature is considerably deflected either way, one of the springs projecting horizontally from it, touches the point of the corresponding screw and thus rings the bell.

As a current regulator, the apparatus shown in the adjacent cut will serve as an example.

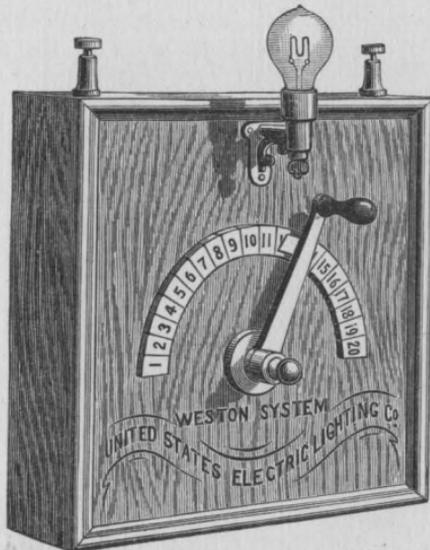


Fig. 24.

The box contains a number of resistance coils, through more or fewer of which the derived current supplying the magnets of the machine is made to pass by turning the handle to the right or left.

When used in connection with an incandescent circuit, a lamp in the same circuit is placed at the top of the box, as shown, and from the appearance of this, the attendant in charge of the machine can judge as to the regulation required.

When used on an arc light circuit, the necessary regulation is indicated by the current indicator, just described.

CUT-OUT AT ENTRANCE OF BUILDING.

The "requirements" say: "Wherever electricity is carried into a building by conductors from an exterior source, a cut-out must be provided at a point as near as possible to the entrance to such building."

This cut-off should be so arranged that it will be manifest at once on inspection whether the current is "on" or "off." If the cut-out is "off," or shows that no current is passing in the building, it should not be disturbed by the patrol or fireman, and as a rule it should not be touched if the lamps appear to be burning regularly; but if there should at any time be any trouble with the lamps, it will then be of great service to have such a cut-out by which they can be controlled.

An essential feature for any cut-out is its automatic action when once started by hand. That is to say the cutting out must not be done by the action of the person operating it only, but being simply started by him, must be completed by the mechanism. Otherwise by a partial movement an arc might be established in the cut-out.

All cut-outs or switches, which shift a current from one circuit to another, should be arranged so as to close one circuit before opening the other, and should be mounted on an incombustible base.

SHEEHY'S CUT-OFF.

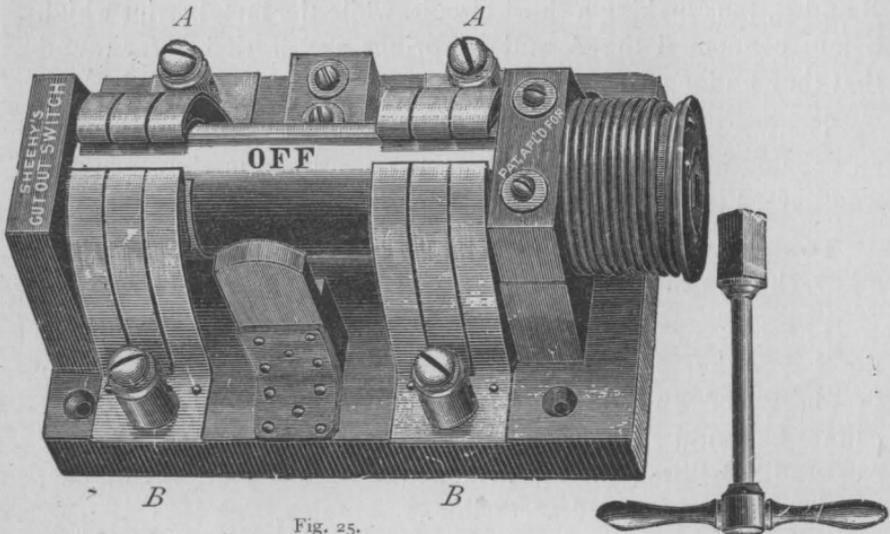


Fig. 25.

Among the various devices to accomplish this end we will first describe that of Mr. R. J. Sheehy.

It consists of a wooden cylinder, so supported and connected with a strong spiral spring wound on it, that it tends to turn in a direction the reverse of the hands of a watch. This motion is, however, checked by a pin projecting from it and catching on the lower part of the small wooden bracket, seen at the middle lower part of the accompanying cut.

If this wooden bracket is, however, pressed away from the cylinder, the latter turns until the pin strikes a permanent stop at the rear.

In its first position, with the pin resting on the wooden bracket, connections are arranged as follows:

The current entering one of the binding screws B, passes by the flat spring connected therewith to a metal strip passing partly round the cylinder, which conveys it to the corresponding flat spring connected with the binding screw A. Thence it goes to the series of lamps and returns to the other binding post A; thence around the cylinder and by the flat springs to the other binding post B, and so out of the building. When the bracket is pulled away, and the cylinder partly revolves, a strip of metal passing lengthwise on it is brought under the flat springs connected with B and B, thus making a short circuit, while the metal strips which before connected the A and B springs, are carried so far round that they no longer touch either springs.

The word "Off," painted on the cylinder, is then seen through an opening in the case inclosing the apparatus, as shown in the wood-cut, Fig 25.

To restore the circuit, the cylinder is turned back by means of a key, shown at the right of the cut.

The box or case inclosing the "cut-out," is locked, and the key either left in some conveniently accessible place or in charge of an attendant on the premises, but in case it cannot be found at the right moment, the glass front of the box can readily be broken, so as to make the releasing latch or wooden bracket above described accessible.

This "cut-out" is largely used by the Brush Company for their arc light circuits. On an incandescent light circuit something having more massive conductors would be required.

It is also desirable that the base of this cut-out should be made of soapstone or other non-combustible material.

THE WESTON CUT-OUT.

The accompanying cut, Fig. 26, shows the outside of another form of "cut-out," designed by Mr. Weston.

As is the case with the Sheehy "cut-out," this also is enclosed in a box which has a lock, and a glass window through which the word "OFF" or "ON" may be seen, according to the condition of the circuit.

When the door is opened, there is then seen immediately in front a knob, on the end of a projecting lever. By pressing this down, a catch is so moved as to release another lever, acted on by a spring, which shifts the circuit from the line running through the building to a short circuit, extending no further than the box.

To restore the current to the circuit of lights, the projecting lever at

the right hand lower corner of the box is pressed down as far as



Fig. 26.

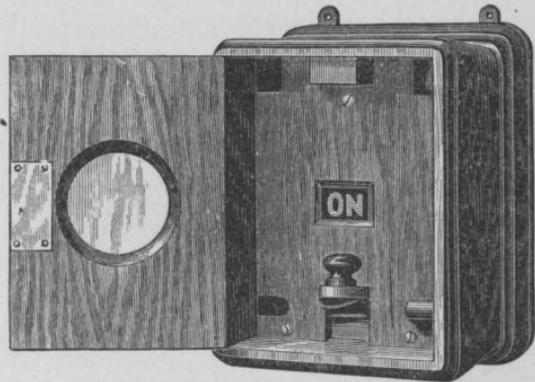


Fig. 27.

it will go. This, while restoring the circuit as above, brings the word "on" into view again through the central aperture.

It seems well in this connection to draw attention to the necessity of a current regulator, such as we have already described; since it is manifest that the use of the cut-out, might cause serious damage in a circuit where a large number of lights were cut out, if there were no current regulator to adjust the strength of the current to the new conditions.

In a circuit of arc lamps, for example, a large number being suddenly cut out, the electro-motive force of the current would be greatly in excess of the requirements of the remaining lamps, and might cause the formation of excessive and dangerous arcs.

INCANDESCENT LIGHT FIXTURES.

As has been already suggested, reasonable allowance must be made for the necessities of the case, in reference to the approach of conducting wires to each other in fixtures.

At first, it was required that a safety catch should be inserted at the base of every lamp; but the accompanying cut, Fig. 28, shows one of the Edison swinging brackets, without a safety catch.

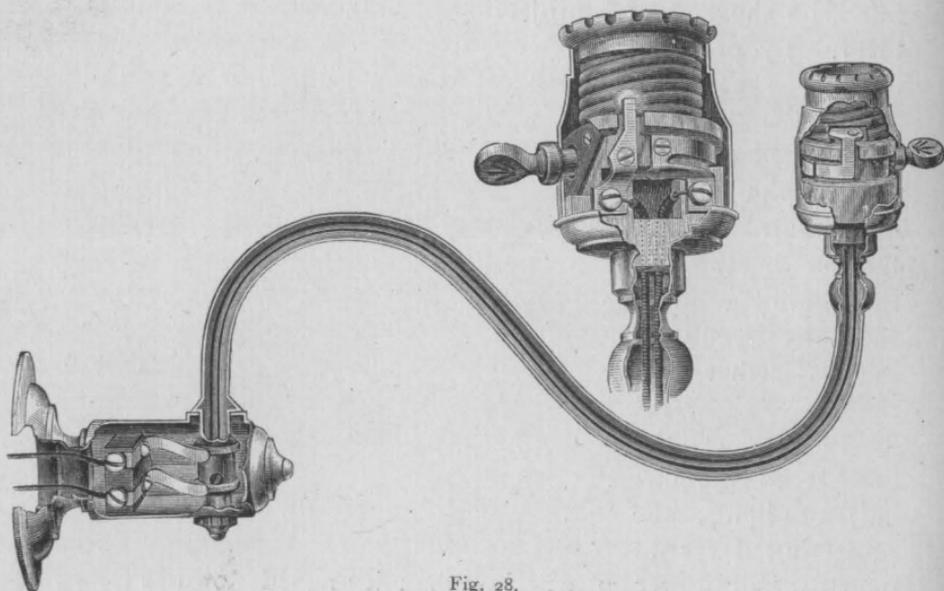


Fig. 28.

The outgoing and return wires for the lamp enter the base of the bracket at the left, and are secured under binding screws on an insulating block to metal springs, which press on circular collars, supported on an insulating support which turns with the bracket. From these collars, insulated wires pass up side by side within the bracket to the base of the lamp holder. Here they connect with the key for turning the light on or off. This key should be arranged upon the sliding contact principle, to prevent the formation of a dangerous arc, and should also have a spring attached so as to secure full contact, and the entire socket should be carefully insulated from the current. As this bracket has no safety catch, special provision must be made to secure the rigid attachment and permanent insulation of the wires, particularly where they emerge from the bracket; and the safety catch must be placed at the first branch where the wire to the bracket leaves a larger conductor.

Recently exceptions have been made in the requirement as to the safety catch, so that it need not be placed at the base of the lamp, but should rather be applied at the entrance to the bracket, or in other words, at the point where the outgoing and return wires begin to be enclosed within the same metallic case or tube. This facilitates the graceful proportioning of the fixture by requiring a less bulky base to the lamp. In cases, however, where this also is inconvenient, the safety catch may be placed at the point where the branch circuit is taken off; but in that case the wires in the fixtures must be secured and insulated as described on page 36.

Where a chandelier with many lights is used, it will suffice to insert a safety catch where the current enters the chandelier, provided the size of wires and total number of lights in the chandeliers is such that the entire current needed for the chandelier cannot heat a single one of the wires to a dangerous extent. In other words, the safety catch must melt with a current insufficient to heat dangerously the smallest conducting wire used in the chandelier.

Another form of bracket for incandescent lights is shown in the accompanying cut, Fig. 29. This is used by the United States Electric Company.

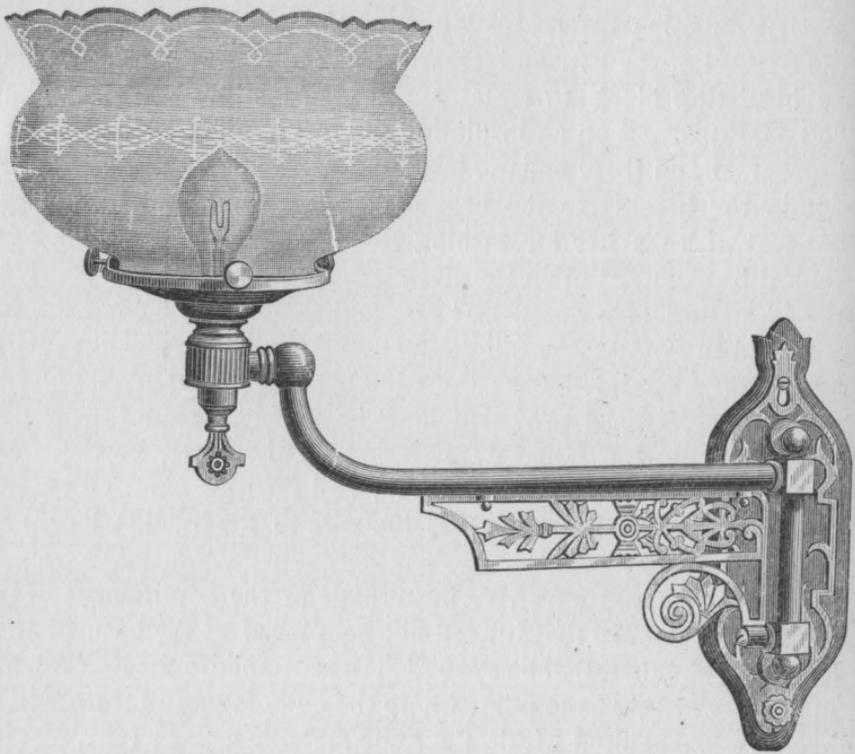


Fig. 29.

The arrangement of the conductors within the lamp socket and bracket is here much the same as in the Edison bracket just described, but there is a difference in the method used for attaching the wires.

Where one of these brackets is to be used there is first attached to the wall a base plate of wood having the shape shown in Fig. 30.

The circuit wires are connected at *c* and *e''*. When the bracket is placed on the plate, electrical contact is made with springs *c* and *d*, and the currents pass from them through the fixtures to the lamp. At *e'* in the wall plate is a fusible safety-catch.

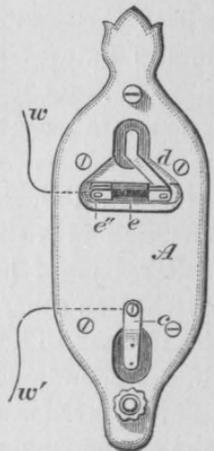


Fig. 30.

STORAGE OF ELECTRICITY.

The same rules which are enforced in reference to the conductors and lamps of other systems apply equally to those parts of the outfit of systems using storage batteries, such as those of Planté, Faure, or the like.

The electric current capable of operating a given number of arc or incandescent lights is identical in all its properties and conditions, whether supplied by a dynamo machine or battery of any sort.

The connecting wires of the storage batteries must also be insulated, and similar precautions in reference to accidental contacts must be taken as with dynamo machines.

TESTING INSULATION OF LINES.

It is desirable for the inspector himself to test the insulation of an electric light line.

This he could readily do, if provided with an apparatus such as that recently designed by Mr. C. J. H. Woodbury, of Boston, Mass., or any other involving like capacities.

The apparatus of Mr. Woodbury is shown in the accompanying cut, and is arranged as follows: "It consists of a Siemen's armature in the field of a battery of five permanent magnets. There is no commutator, and the alternating current excites an electro-magnet which vibrates a striker, between two small gong bells, in the usual manner. A polarizer over the electro-magnet removes any residual magnetism. In the circuit, at the end of the case, are two reels, each of which carries forty feet of steel ribbon with spring clamps at the ends. These reels, and the wheel which revolves the armature by means of a quarter-turn belt, are turned by a crank which fits like a clock key, and when not in use is held by a spring clip, as shown in the engraving. The armature is wound with number forty wire, and measures two and three-quarters inches long, and three-quarters of an inch in diameter. The whole apparatus is contained in a hard rubber case four inches wide, an inch thick, and eight inches long, and weighs twenty ounces.

The bell will ring, when the magneto is working, through an external resistance of four thousand ohms.

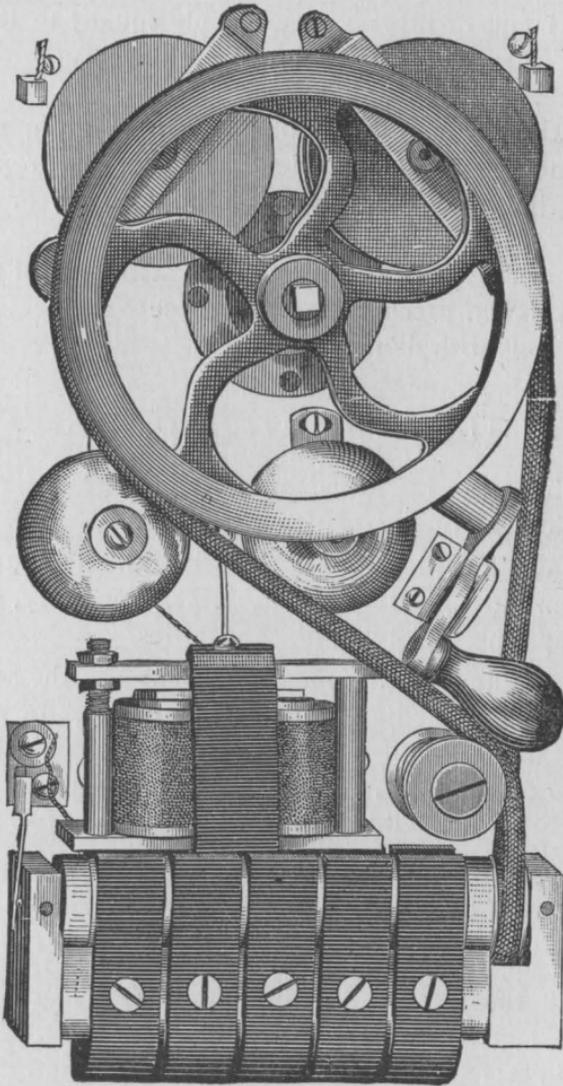


Fig. 31.

It was supposed that on long circuits the surface of the conducting wires might act as a condenser, and the static charge ring the bell, but such has not been the case, even with circuits

containing six miles of number six wire. This instrument has been in constant use for over eight months."

When employed for testing a line, the end of one of the steel tapes is put in connection with the earth, by being attached to a gas or water pipe, or other conductor in good connection with the ground, and the other tape is attached to the nearest wire or fixture where connection can be secured without disturbing the permanent insulation.

Then on turning the handle of the machine, the bells will ring if there is a lack of insulation anywhere on the line, but not if its insulation is perfect.



CONCLUSION.

In presenting this little work to those interested in the subject discussed, its authors desire to express their own realization of its probable incompleteness.

The subject is essentially a new one, in which ideas are likely to be modified by experience and by the introduction of new methods.

All the present writers hope to do in this work is to present an outline which may be filled up to completeness from time to time as the subject develops itself.

Properly constructed and guarded against accident by the requisite precautions, electric lighting they believe to be as safe as any other method of illumination, and to aid in the securing of these conditions of safety is the object of the present treatise.

FORM OF SURVEY AND REPORT USED BY

THE NEW YORK BOARD OF FIRE UNDERWRITERS,

BOREEL BUILDING, 115 BROADWAY.

No.

SURVEY AND REPORT OF ELECTRIC LIGHT EQUIPMENT,

In Premises of No.

The lights are of the patent. The dynamo machine has capacity for lights, and is located

When electricity is supplied from Central Station, state where wires enter and leave the building,; Distance from each other,; enclosed in tube properly placed, with "cut out" box, located on story.

Are the outside wires on poles exclusively, or on building

	In Sub-Basement.	Basement.	1st Story.	2d Story.	3d Story.	4th Story.	5th Story.
Number of Arc Lights, -							
Number of Incandescent whole Lights, - -							
Number of Incandescent half Lights, - -							

Are all the arc lights provided with globes enclosed at base?

Are spark arrestors or wire netting required? If so, where?

Are the arc lamps provided with automatic switch?

Are the incandescent light wires provided with fusible safety catches at each branch connection? If not, where?

What means are provided to call attention of person in charge of the dynamo electric machine to excessive flow of current?

WIRES.

- Size of wire used..... How are they insulated?.....
- Are they fastened as called for in Standard?.....
- Is the proper distance preserved between wires?.....
and other conductors?.....
- If not, are they rigidly secured and separated from each other, and from
other conductors, by some solid non-conducting material of at least
one-half inch in thickness?.....if not,
state where and how insulated?.....
- Is any portion of the conductors enclosed so that they cannot be
inspected?..... Where?.....
- Where they pass through walls, floors, etc., are they enclosed in proper
tubes?..... Are all joints made in proper manner?.....
- Is any portion of the circuit within building exposed to water?.....
- Are the lamps and chandeliers properly insulated?.....
- If not fully insulated, are the exposed parts protected by screen, or otherwise,
from contact?..... Is any portion of the circuit grounded?.....
- Do you know of any reason why a Certificate should not be granted for the
use of these lights?.....

FORM OF CERTIFICATE AND STUB,
USED BY THE NEW YORK BOARD OF FIRE UNDERWRITERS.

No.
New York, 188

No.
New York, 188

THIS CERTIFIES that the equipments of the.....

Premises,
in premises No. this city,

.....
are in full compliance with the Standard requirements of this Board,
adopted as per In-

Company,
spector's Report, dated and numbered.....

.....
No alterations to be made in the manner of equipment without
written permission from this Board.

Date of Inspector's Report,.....

No. of Report,.....
To M.....

Superintendent.

The following are the full Standard Requirements of the New York Board of Fire Underwriters, adopted January 12, 1882, and endorsed by the National Board of Fire Underwriters May 25, 1882.

ELECTRIC LIGHTING.—CAPACITY OF CONDUCTORS.

FOR ARC LIGHTS.—The conductor must have a weight per running foot at least equal to that of the wire (or parallel group of wires), constituting the main circuit of the magnetic regulator of the electric lamps, or of the armature of the machine employed, whichever of these is the largest.

FOR INCANDESCENT LIGHTS.—Wherever a connection is made between a larger and a smaller conductor at the entrance to or within a building, some approved automatic device must be introduced in the circuit of the smaller conductor, whereby it shall be interrupted whenever the current passing through it is in excess of its safe carrying capacity.

The safe carrying capacity of a wire is that current which it will convey without becoming painfully warm when grasped in the closed hand.

INSULATION.

All wires, machines and lamps to be so mounted and secured as to insure complete and continuous insulation, with the exception of those parts (such as portions of the lamps or machines, for example) where insulation is impossible, and in this case accidental contact with exterior objects must be prevented by appropriate screens or the like.

In no case must "ground circuits" be employed, or any portion of the system be allowed to come into conducting connection with the earth through water or gas pipes or otherwise.

Exposed wires must be covered with at least two coatings, one of insulating material next the wire, of a thickness and material approved by the Board, and another outside of this, of a material calculated to protect the former from abrasion or other mechanical injury.

Where there is a possible exposure to water, the first or second coating must be impervious to that fluid.

Wherever electricity is carried into a building by conductors from an exterior source, a "cut out" must be provided at a point as near as possible to the entrance to such building.

The outgoing and returning wires for Arc Lights should enter and leave each building at points at least one foot from each other.

The wires passing through the exterior walls of a building should be firmly incased in substantial tubes of non-conducting material, not liable to absorb moisture, and placed in such a manner as to prevent rain water from entering the building along the wire.

In running along walls and the like, wires should be rigidly attached to the same by non-conducting fastenings (the wires themselves being well insulated), and should not be hung from projecting insulators in loose loops.

All wires should be placed at a distance of eight inches for Arc Lights and two and one-half inches for Incandescent Lights from each other, and wherever they approach any other wire or conducting body capable of furnishing another circuit or ground connection, they must be rigidly secured and separated from the same by some continuous solid non-conductor, such as dry wood, of at least one-half inch in thickness.

Wherever wires are carried through walls, floors or partitions in buildings, they must be surrounded by a special insulating tube of substantial material.

All joints in wires must be made in such a manner as to secure a perfect and durable contact. Continuous wires (without joints) to be used as far as possible.

GLOBES.

Arc Lights must be protected by glass globes, enclosed at the bottom to prevent the fall of ignited particles, and where inflammable materials are present below the lamps, a wire netting must be added to keep the parts of the globe in place in case of its fracture during use.

All broken and cracked globes to be at once replaced by perfect globes.

In show windows and other places where inflammable materials are near the lights, spark arrestors shall be placed at the top of the globes.

AUTOMATIC SHUNT.

Wherever a current of such high electro-motive force is employed, that if concentrated on one lamp of the series, it would produce an arc capable of destroying or fusing parts of such lamp, an automatic switch must be introduced in each lamp, by which it will be thrown out of circuit before the arc approaches any such dangerous extent.

Companies furnishing electricity from central stations must enter into an agreement with the New York Board of Fire Underwriters, binding themselves to test their lines for ground connections at least *once* every day (and preferable three times per day), and to report the result of such tests to the Board weekly.

Means by which those in charge of the dynamo-electric machines will be warned of any excessive flow of current, or means whereby the same will be automatically checked, must in all cases be provided.

It is earnestly recommended by the National Board of Fire Underwriters that local boards, having jurisdiction in places where this hazard has been, or is likely to be; introduced, adopt the

above standard, using the following form of endorsement for the privilege wherever granted :

Privileged to use Electric Lights in the above mentioned premises when the entire equipment is in full compliance with the standard of the New York Board of Fire Underwriters, adopted January 12, 1882, and a certificate is obtained from Board of Fire Underwriters to that effect.

It being understood that no alterations shall be made in the equipment after certificate is issued, without written consent from said Board of Fire Underwriters.

Attached to Policy No......

In places having no local board inspectors, it is recommended that the Underwriters there select some electrician to make thorough inspection of electric equipments, and certify to same when found in full compliance with standard; and it is also recommended that before any inspection is made, it shall be required of the Electric Company introducing the equipments, that they shall furnish a written statement to the effect that the entire equipment is finished, and that the same has been inspected by them, and found to be in full compliance with the Underwriters Standard Requirements.

Such statement from the Electric Company, frequently saves the Insurance Inspector the necessity of a second visit.

The following form of permit is recommended where the examination is made by other than Local Board Inspectors, viz. :

....., Electrician, having filed a certificate with Insurance Agent, certifying that the entire electric equipment in the above mentioned premises is in full compliance with the standard of the New York Board of Fire Underwriters, adopted January 12, 1882, privilege is hereby granted to use Electric Lights in said premises.

It being understood that no alteration shall be made in said equipment without the written consent of said , Electrician, and of this Company.

..... Agent.

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