MODERN

Electrical Construction

A RELIABLE, PRACTICAL GUIDE FOR THE BEGINNER IN ELECTRICAL CONSTRUCTION SHOWING THE LATEST APPROVED METHODS OF INSTALLING WORK OF ALL KINDS ACCORDING TO THE SAFETY RULES OF THE

National Board of Fire Underwriters

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Illustrated

FIFTH EDITION—REVISED AND ENLARGED

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PREFACE

In this volume an attempt is made to provide the beginner in electrical construction work with a reliable, practical guide; one that is to tell him exactly how to install his work in accordance with the latest approved methods.

It is also intended to give such an elaboration of "safety rules" as shall make the book valuable to the finished workman as well. To this end the rules of the "National Electrical Code" of the National Board of Fire Underwriters have been given in full, and used as a text in connection with which there is interspersed in the proper places a complete explanation of such work as the rules may apply to. This method of teaching and explaining practical electricity may at first glance seem somewhat haphazard, but it resembles very closely the actual method by which the most successful, practical workmen have learned the trade. It is thought that explanations pertaining directly to the work in hand will be more deeply considered and more likely to be fully comprehended than explanations necessarily more abstract.

It should be noted that, while the rules published in the "National Electrical Code" are standard and work done in conformity with them will be first-class, several of the larger cities have ordinances governing electrical work which conflict in some details with these rules. Workers in such cities should, therefore, provide themselves with copies of these ordinances (usually obtainable without charge), and compare them with the rules given in this work. It is necessary for the electrical worker at all times to keep himself posted, for safety rules are liable to change.

The tables concerning screws, nails, number of wires that can be used in conduit, etc., are especially prepared for this volume, and give to it particular value for practical men.

THE AUTHORS.

PREFACE TO SECOND EDITION

The favorable reception which the first edition of this work has received at the hands of electrical workers generally has induced the authors to prepare this, the Second Edition. Considerable new matter, notably a section on Theater Wiring, has been added. All the necessary alterations and additions have been made in the text to conform to the latest issue of the National Code, together with the required explanations and illustrations. Other sections have been extended and the whole work has been carefully gone over and revised wherever the progress of the art has made it desirable.

THE AUTHORS.

PREFACE TO THE THIRD EDITION

In a work of this kind it is of prime importance that it be kept abreast of the times. Safety rules are liable to change, in fact must do so to adapt themselves to the steadily increasing number of new inventions and devices brought upon the market.

This work having found sufficient favor in the eyes of many instructors to warrant its adoption as a text-book, is to be revised and new matter added as often as notable changes in methods of construction or safety rules make it appear desirable.

The latest additions and modifications of the "National Electrical Code" are contained in an appendix which should be consulted. New illustrations are inserted in the body of the work as needed.

THE AUTHORS.

PREFACE TO FOURTH EDITION

The favor with which former editions of this work have been received and the general reliance placed upon it by electrical workers everywhere has made it practically mandatory that it be kept strictly up-to-date. Since the National Electrical Code is subject to bi-ennial revision a similar revision of this work is advisable and it is the purpose hereafter to provide such. This work consists really of two parts, one being a literal transcription of the National Electrical Code, and the other consisting of comments and practical hints by the authors with the object of instructing wiremen in the installation of electrical apparatus.

While long experience has given the authors a peculiar fitness to speak upon the matters considered, it is, nevertheless, thought advisable to warn the reader that on all points that may not seem perfectly clear and harmonious it is best to consult the inspection department having jurisdiction; in other words, the authors wish distinctly to waive all claims to speaking officially on any part of the Code.

It has been the aim of the authors to treat every branch of electrical construction work which may come under the supervision of a practical wireman and for this reason a chapter on electric sign hanging and some notes on moving picture booths and installations have been added.

This work deals only with construction. Should any wireman be called upon to advise in the layout of lighting installations much information of a useful and practical nature will be found in a recent work entitled "Modern Illumination, Theory and Practice" which may be considered as supplementary to this work.

THE AUTHORS.

CHAPTER I.

The Electric Current.

It is quite customary and convenient to speak of that agency by which electrical phenomena, such as heat, light, magnetism, and chemical action are produced as the electric current. In many ways this current is quite analogous to currents of air or water. Just as water tends to flow from a higher to a lower level, and air from a region of greater density or pressure to one of lesser density, so do currents of electricity flow from a region of high pressure to one of low pressure. Currents of electricity form no exception whatever to the general law of all action, which is along the lines of least resistance. It must not be understood, however, that electricity actually flows in or along a conductor, as water does in a pipe, and the analogy must not be carried too far, for the flow of water in pipes is influenced by many conditions which do not influence a flow of electricity at all, and vice versa; there are conditions surrounding conductors, which influence the flow of electricity which do not affect the flow of water.

Above all, let it be understood that electricity is not independent energy, any more than the belt which gives motion to a pulley is. In other words, it is not a prime mover, it is simply a medium which may be used for the transmission of energy, just as the belt is used. To use electricity as a medium for the transmission of energy, it must be, we may say, compressed, or, to use a more properly technical expression, a difference of potential or pressure must be created in a system of conductors. This is very similar to the use of air for power transmission; this must also be compressed so that a difference of pressure exists within a system of piping.

It is the flow of electricity or air which takes place when switches or valves are operated and which tends to equalize this pressure, i. e., flow from high to low pressure, that does our work. The real energy, however, (so far as we are concerned), to which we must look for our initial motion in either case is derived from the coal which generates steam; or, in the case of water-driven machinery, the rays of the sun which evaporate water, allowing it to be carried to higher levels, from whence it flows downward over dams and falls on its way back to the lowest level. In the battery, the real energy is that of chemical action, which is transformed into electrical energy.

The flow of current can take place only in a system of conductors which usually, for convenience, are made in the form of wires. The current for practical purposes may be considered as flowing along such wires only. It is not, how-

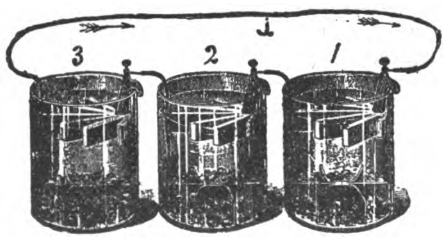


Figure 1

ever, necessary that these wires should be of any particular size, or consist all of the same material. In an electric battery, part of the circuit consists of the liquid contained within the battery; the rest being made up usually of wire. In an incandescent light circuit part of the circuit consists of the lamp filament (usually carbon), while the balance of the circuit consists of copper wire.

The flow of current is also said to have a certain direction; that is, it is noticed that many of its effects are reversed when the terminals of the battery are reversed. Referring to Fig. 1, which shows a battery of three cells, the current flows from the copper element at bottom of jar 1, along the wire to the zinc element at top of jar 2, thence through the liquid to the copper element at bottom of jar 2, and from there to the zinc at top of jar 3, etc., and finally through the wire *a* back to the starting point. Within the battery the current flows from the zinc to the copper and the decomposition of the zinc generates the current. In the wire outside of the battery the current flows from the copper to the zinc as indicated by arrows. The combination of battery and wire is known as an electric circuit. The current will flow in this circuit only while it is complete, that is while each wire connects to its proper place as shown. If any wire is disconnected, the current flow will cease. Such a circuit is said to be *open*, but when all connections are properly made it is said to be *closed*.

Work can be obtained from a flow of current in many ways. If the current be forced to flow over a wire which is very small in proportion to the current carried, it will be heated thereby and finally melted if the current is excessive. This is how electric light is obtained.

If a wire carrying current be wound many times about an iron bar this bar becomes a magnet; that is, while the current is flowing around it, the bar has the power to attract other objects of iron or steel. The bar if made of well annealed iron will be a magnet while current is flowing around it, but will cease to be magnetic whenever the current flow ceases. Upon this fact the operation of electric bells, telegraph instruments and motors is based.

If a current of electricity flow through a properly arranged "bath," one of the plates will be gradually consumed and the other increased in weight. This effect is made use of in electro-plating, etc. If the jar contains water slightly acidulated and the current flows through it, the water will be decomposed and oxygen and hydrogen gas will be formed. This and many kindred effects are daily used in thousands of chemical laboratories.

If a wire carrying an electric current be placed very close to another wire forming a closed circuit, a wave of current will be induced in that wire every time the current in the other is made or broken, i. e., whenever it starts to flow or stops flowing. This fact forms the basis of the alternating current transformer.

All of these facts are used sometimes together, sometimes singly in measuring the electric current.

Conductors and Insulators.

Electrically speaking, all substances are divided into two classes. They are either conductors or insulators. By this is not meant that some substances can carry no current at all, for, as a matter of fact, there is no such thing as either a perfect conductor or a pecfect insulator. A current of electricity can be forced through any substance, provided the pressure (E. M. F.) be made great enough, and there is no easier path open to the current. The two terms, conductor and insulator, are relative terms and must be understood simply to mean that the electrical resistance of a good conductor is infinitesimally small as compared to that of a good insulator. The lower the specific resistance of any substance, the better its conducting qualities; the higher the specific resistance of any substance, the better will be its insulating qualities.

At the left is given a list of good conductors, in the order of their conductivity, the figures representing the relative conductivity of these metals. A list of insulators is given at the right; all of these are more or less affected by moisture, losing their insulating qualities when wet.

Silver	100.0	Dry air.	Fiber.
Copper	94.0	Rubber.	Wood.
Gold	73.0	Paraffin.	Shellac.
Platinum	16.6	Slate.	
Iron	15.5	Marble.	
Tin	11.4	Glass.	
Lead	7.6	Porcelain.	
Bismuth	1.1	Mica.	

Pressure or Electro-Motive Force.

Currents of electricity flow only in obedience to electrical pressure. This pressure is measured and expressed in *volts,* the unit of electrical pressure being the *volt.* If we speak of water or steam pressure, we speak of it in pounds, the pound being the unit of measurement. In speaking of electrical pressure we refer to it as of so many *volts.* There is no direct connection between the pound and the volt, but each in its place means about the same thing.

The *volt* is defined as that difference of potential (pressure) that must be maintained to force a current of one *ampere* through a resistance of one *ohm.*

If we have a resistance greater than one ohm and wish to send a current of one ampere through it, we can do so by increasing the pressure or voltage, as it is termed, accordingly. The current flowing in a circuit can also be reduced by reducing the *voltage.*

The ordinary incandescent lamps operate at about 110 *volts* pressure, although some are built for 220 volts. An electric bell requires about 2½ volts (a battery of 2 cells) for proper operation.

Resistance.

We have seen that a flow of current always takes place along or in a conductor. Every conductor, no matter how large or small it may be, offers some resistance to this flow of current just as the water pipe offers more or less resistance to the flow of water. This resistance may be measured and expressed in *ohms;* the unit of electrical resistance being the *ohm.* The *ohm* is defined as that resistance which requires a difference of potential of one volt to send a current of one *ampere* through it. If we should desire to send a greater current through any resistance, we can do so by increasing the pressure, just as we can increase the flow of water in a pipe by increasing the pressure or head of water in the tank that supplies it. If the pressure is fixed we can decrease the current by using a wire of greater resistance or increase it by using wires of lesser resistance.

The *ohm* is the resistance of a column of mercury 106.2 centimeters long (about 3½ feet) and one square millimetre (about .0015 sq. in.), in cross-section, at the temperature of melting ice.

The resistance of a No. 14 copper wire about 380 feet long is equal to one ohm.

The resistance of all conductors increases directly as the

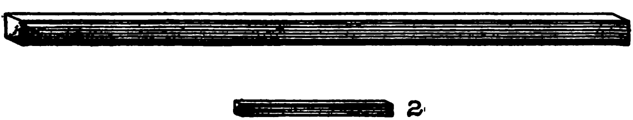


Figure 2

length and decreases as the cross-section increases. In Figure 2 the resistance of the two bars of copper is exactly equal. Bar No. 1 having a cross-section of 4 square inches and being 4 feet long, while bar No. 2 has a cross-section of only 1 square inch and is only one foot long. If bar No. 1 were reduced to a cross-section of 1 square inch, it would become 16 feet long and would have a resistance 16 times as great as that of bar No. 2.

Current.

The electric current is the result of electrical pressure (volts) acting through a resistance, and is measured in *amperes*, the *ampere* being the unit of current strength. The *ampere* is defined as that current which will flow through a resistance of one *ohm* when a difference of potential or pressure of one volt is maintained at its terminals.

The *ampere* expresses only the rate of flow, not the quantity. Knowing the amperes if we would know the quantity, we must multiply by the time that the rate of flow continues. The rate of flow is analogous to the speed of a train; unless we know how long the train is to maintain a certain speed, we have no idea how far it is going.

Quantity in electricity is measured in *coulombs*. The *coulomb* is the quantity of current delivered by a flow of one ampere in one second.

Ohm's Law.

Ohm's law expresses the relation of the three principal electrical units to each other and forms the basis of all electrical calculations.

This law states that in any electric circuit (with direct current) the *current* equals the *electro-motive force* divided by the *resistance*. The current, we have already seen, is the medium which does our work. Current flow, we see from this law, can be increased either by increasing the electro-motive force, or electric pressure, which causes the flow; or by decreasing the resistance which tends to prevent current flow.

Expressed in symbols it is this: $I=E/R$; where I stands for current, E, for electro-motive force, and R for resistance. If, as an example, we have an electro-motive force (which we shall henceforth designate by the customary abbreviation, E. M. F.) of 110 volts and a resistance of 220 ohms, the resulting current will be 110 divided by 220 = ½ ampere, being approximately the current used in a 16 cp. incandescent lamp at 110 volts. Thus it will be seen that by a very simple calculation we can find the current flow in any conductor if we but know the E. M. F. and the resistance of that circuit.

This formula can also be used to find the E. M. F., if we know the value of current and the resistance, since E divided by R=I; I times R must equal E. If the current and resistance are known, we need only to multiply them together to find the E. M. F.; I×R=E. Knowing the current and E. M. F., we can find the value of the resistance by dividing the E. M. F. by the current; E/I=R.

As a practical application of these formulas: If we wish to know how much current a certain E. M. F. can force through a certain resistance, we must divide the E. M. F. (volts) by the resistance (ohms.) If we wish to know what E. M. F. (volts) will be necessary to force a certain current (amperes) through a certain resistance, we need only multiply the current (amperes) to be obtained by the resistance in ohms. If we wish to know how much resistance (ohms) must be placed in a circuit to keep down the current flow to a certain limit, we need only divide the E. M. F. (volts) by the desired current (amperes); the result will be the value in ohms of the required resistance.

Power.

The power consumed or transmitted in an electric circuit equals the product of the volts and amperes; pressure and current.

To find the power of a steam engine, we must know the pressure of the steam and the quantity used; the power contained in the water of a dam depends upon its volume and its head. The power we can obtain from the wind depends upon its speed and the surface we expose to it which also measures the quantity.

All of these cases are analogous and similar. Power expresses the rate of doing work, thus the rate of work is the same whether we are lifting one pound at the rate of 100 feet per minute, or 100 pounds at the rate of one foot per minute. The unit of electrical power is the *watt*. It is the power expended in an electric circuit when one ampere flows through a resistance of one ohm, or when a difference of potential of one volt is maintained in a circuit having a resistance of one ohm. In an electric light circuit, for instance, as far as the power is concerned, it is immaterial whether each lamp requires 110 volts and ½ ampere, or 55 volts and one ampere, or 220 volts and ¼ ampere. The power (watts) expended in an electric circuit is always equal to the volts multiplied by the amperes; thus, one ampere at 1,000 volts is equal to 100 amperes at 10 volts, or to 200 amperes at 5 volts. In any power transmission whenever the pressure (volts) is lowered, the current (amperes) must be increased or the power (watts) will fall off, and, on the other hand, whenever the pressure is increased the current may be decreased.

Instead of multiplying volts by amperes, we can find the power in an electric light circuit by multiplying the current by itself and then by the resistance; or the E. M. F. by itself and divide by the resistance.

Thus knowing the volts and the amperes, we use the formula $E \times I = W$. Knowing only the amperes and the ohms, we may use the formula, $1^2 \times R = W$; and lastly, knowing only the volts and ohms, we use the formula, $E^2/R = W$.

In the above E stands for E. M. F., or volts; I for current or amperes; and R for resistance or ohms.

Divided Circuits.

Currents of electricity always flow along the paths of least resistance just as currents of water do. Water, it is well known, will not flow over the top of a mill dam while

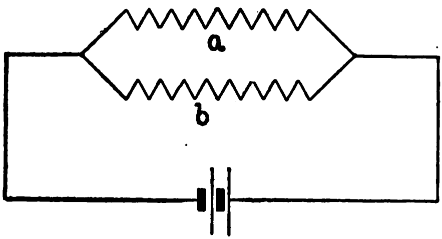


Figure 3

there is an opening alongside of it through which it can flow. If a barrel of water be provided with two openings, one large opening and one small, a much larger quantity will flow out through the large opening than through the small. This is because the resistance to the flow of water of the large opening is so much less than the resistance of the small opening.

An electric current will act in just the same way; the conductor having the lesser resistance will carry the greater current. If we know the resistances of the different paths open to a certain current we can determine to a nicety how much current will flow in each. In Figure 3, which represents diagramatically a battery of two cells and an electric circuit, the resistance of the two paths, *a* and *b*, is equal to

10 ohms each, and the current will divide equally between them. If the resistance of *a* were 5 ohms, and that of *b*, 10 ohms, two-thirds of the total current would pass through *a* and the one-third through *b*.

In all such divided circuits, the current is always inversely proportional to the resistance and the simplest way to find the current in each is to add the resistances of the two circuits; for instance as above, 5 plus 10 equals 15; now 5/15 of this current will flow through the 10 ohms and 10/15 of the current will flow through the 5 ohms.

To determine the combined resistance of the two wires, *a* and *b*, we need simply to consider them as made into one wire. If they are both alike, they would, if made into one wire, be twice as large as either one is at present, and would then have only one-half as much resistance as either one had before; for the resistance of any conductor increases directly as its length, and decreases as the cross-section increases. The combined resistances of any two conductors can be found by multiplying their two resistances together and dividing this product by their sum. Thus, again taking the value of *a* and *b* as 10 ohms each, 10×10 equals 100, this divided by 10 plus 10 equals 5, which is the combined resistance of the two.

If we have a large number of branch circuits as shown in Figure 4, which represents diagramatically an incandescent

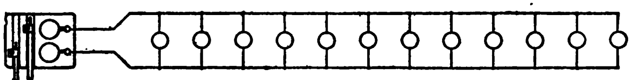


Figure 4

electric light circuit of 12 lights (which is equal to 12 separate circuits, since each lamp really forms a circuit by itself), we can find the joint resistance of the 12 by proceeding as before; that is, multiplying together the resistance of the first and second lamp and dividing by the sum of these resistances; next take the result so obtained (which is the combined resistance of the first two lamps) and with it multiply the resistance of the third lamp and divide by the sum as before. By repeating this operation and always treating the joint resistances already found as one circuit, the joint resistance of any number of such circuits can be found. Another and a very much quicker way consists in using the following formula: The joint resistance of any number of parallel circuits is equal to the reciprocal of the sum of the reciprocals. The reciprocal of any number is 1 divided by that number. If we have three circuits, having respectively 10, 20, and 30 ohms resistance, we proceed in the following way: The reciprocal of 10 is 1/10, of 20, 1/20, etc., the joint resistance, therefore, is 1/10 plus 1/20 plus 1/30 equals 11/60, and 1 divided by this number which is 5 5/11.

These methods are only necessary when the resistances are of different values. When all of them are alike, as is usual with incandescent lights, the resistance of one lamp needs only to be divided by the number of lamps to find the joint resistance. Thus, supposing each of the 12 lamps to have a resistance of 220 ohms, the joint resistance of the circuit would be 220/12=18 1/3.

CHAPTER II.

Electric Bells.

We are now in a position to apply the electrical laws we have just discussed practically, and for this purpose may take up electric bells and bell circuits.

Figure 5 shows an electric bell, push button and battery, all connected up and complete. The action of the bell when

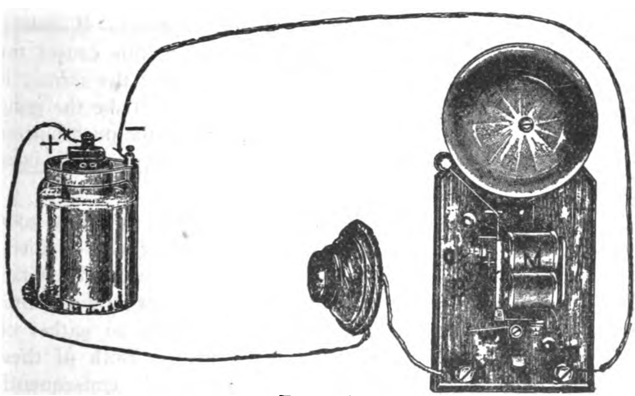


Figure 5

fully connected is as follows: Pressing the push button closes the circuit and current at once flows from the carbon pole marked + through the push button to the binding post A on the bell frame, thence along the fine wire W to the iron frame-work supporting the armature, B. This framework is in electrical connection with B. The armature, B, is provided with contact spring S, which normally rests against the adjusting screw, C. The current now passes from the contact spring to the adjusting screw and from it to the wire wound on the magnets, M, around the many turns of wire to the binding post, D, and back to the zinc pole of the battery marked —.

The current circulating many times in the wire wound on the spools of M makes the iron cores magnetic so that they now attract the armature B. When this armature is attracted, it moves towards the magnets, M, and carries the small contact spring with it, thus breaking the connection between C and S.

This stops the current flow and the magnets, M, are at once demagnetized, thus releasing the armature B, which flies back and again closes the circuit at CS, this causes the armature to be attracted again and once more the circuit is broken. In this way the armature is made to strike the gong continuously while the circuit is kept closed at the push button. When the button is released, the circuit is permanently open and the bell at rest.

In the figure there is shown only one cell, this, if a good form is selected, is sufficient for a new bell if the circuit is not long. When, however, the bell is used much the contact points are eaten away by the little sparks occurring every time the bell breaks the circuit. Dirt is also likely to gather on them and prevent good contact being made. Both of these factors add resistance to the circuit, and consequently lessen the current flow.

We have seen before that the current equals the E. M. F. divided by the resistance, and in order to obtain the necessary current flow to operate the bell, we may either clean the contact points to lessen the resistance, or increase the E. M. F. by adding another cell in series with the first.

The latter expedient is by far the better, because it gives us a little surplus of power which is very useful to overcome variations in adjustment of the contact spring, loose contacts, dirt, etc. We should avoid using too many cells as well as not enough. If too many cells are used, there

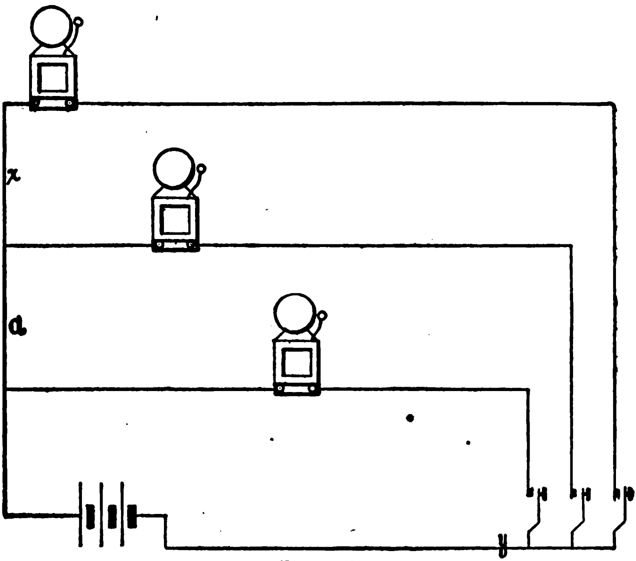


Figure 6

will be much unnecessary damage done to contact points by the larger sparks.

If the circuit is very long, the great length of wire will also provide additional resistance. This can be overcome in two ways, by increasing the E. M. F. as above, or by using larger wires. We have already seen that the larger the wire, the less will be its resistance. It is common practice to use

No. 18 copper wire for all ordinary distances and for single bells. With large bell systems, it is customary to use No. 16 or 14 for the main wire, which leads to all of the bells and may be called upon to supply several bells at the same time. Figure 6 shows a diagram of such a system and in case the three push buttons are used at the same time, three times as much current will flow in the main or battery wire *a* as in either of the other wires.

We have seen before that currents of electricity divide among different circuits in the inverse ratio of their resistances. In other words, the circuit having the least resistance will carry the most current. If our bell system, Figure 6, be "grounded" at the two points x and y (i. e., bare wire in contact with metal parts of buildings which are connected together) the current instead of flowing through the longer circuit and the bell, will flow through the short circuit and leave it impossible to operate the bells. If the contacts, at x and y are poor, i. e., of high resistance, only a small part of the current will leak from one to the other. In such a case, the bells may work properly, but the battery will soon run down and there is a strong likelihood that one of the wires will be eaten away through electrolytic action. To prevent troubles of this kind, bell wires should be well insulated and kept away from pipes or metal parts of building. Damp places should also be avoided and special care is recommended for the battery wire *a*, Figure 6. For further information concerning diagrams, etc., of bell circuits the reader is referred to *Wiring Diagrams and Descriptions* by the authors of this work, Fred J. Drake & Co., Chicago.

Bell wires are usually run along base boards, over picture mouldings, etc., in some cases they are also fished as explained further on. Batteries should be located in cool, dry places, where they are not liable to freeze, and where they are readily accessible as they must be kept nearly full of water and must be recharged from time to time.

The Telephone.

The principle and action of the Bell telephone can be best explained by reference to Figure 7. In this figure, A represents the transmitter, and B, the receiver. The essential parts of the transmitter are: the diaphragm, *a;* an electric circuit, containing a battery, *b,* and consisting of the wires, *c*, c^1 and partly wound upon an iron core, *d.*

This electric circuit, it will be seen from the figure, connects with one pole to the diaphragm, *a,* and with the other to a small metal plate, *e.* Between the diaphragm, *a* (which is a plate of very thin iron), and the plate, *e,* there are many small pieces of carbon which complete the circuit. When now a party speaks into the mouthpiece of the transmitter,

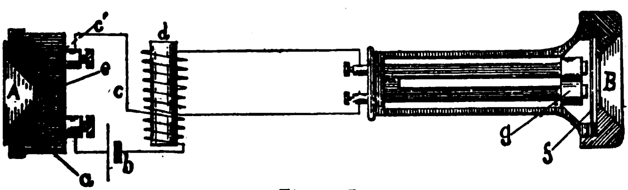


Figure 7

the sound waves cause the diaphragm, *a,* to vibrate; the rate of vibration and character of the vibrations being an exact duplication of the voice speaking into it. These vibrations cause the small pieces of carbon between the diaphragm and the back plate to be alternately compressed and allowed to expand. Now the resistance of these carbon pieces is decreased as they are tightly pressed together, and again increased when the pressure is released. Therefore the current of electricity flowing through them varies continuously while the diaphragm is in motion.

This varying current circulates around the lower part of the iron core, *d,* and the two windings upon it form an ordinary induction coil. Every variation of current strength in the circuit of the transmitter is by means of it reproduced in the circuit of the receiver, *B*.

The essential parts of the telephone receiver are: The diaphragm *f*, very similar to that of the transmitter, the two magnets, *g*, and the electric circuit coming from the induction coil of the transmitter. The electric circuit, we have already seen, is traversed by electric currents exactly like those that flow in the circuit of the transmitter. These currents pass around electro-magnets, *g*, and attract the diaphragm, *f*, more or less strongly in proportion to the varying degrees of current strength.

In this manner the diaphragm, *f*, of the receiver is made to vibrate in exact unison with that of the transmitter, and thus to reproduce exactly the sounds given to the transmitter.

The transmitter is not absolutely necessary for the re-

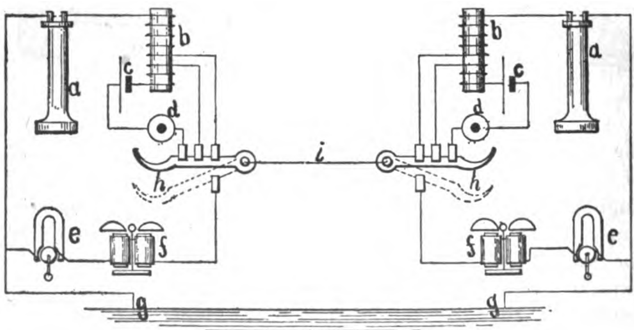


Figure 8

ceiver can be used as such, and in fact was so used at first. Lines of short distances can be operated without transmitters, but the speech will not be as plain.

Figure 8 is a diagram of the connections of two telephone instruments together with the necessary call bells. When the lines are not in use, the receivers, *a*, are hanging on the hooks, *h*, holding them down as shown by dotted lines. This leaves the circuit complete through the earth, *g*, magneto generator, *e*, bell *f*, line *i*, and duplicates of these parts at the right. When now the magneto generator is operated both bells will ring. When the receivers are removed, a spring forces the hook upwards making the connection shown in solid lines. This closes the battery circuit which must be open when the instrument is not in use or the battery will run down.

The talking circuit is now complete from earth, *g*, through the receiver, *a*, induction coil, *b*, line *i*, and duplicates of these parts at the right.

The Induction Coil.

Figure 9 is a diagramatic illustration of an induction coil as used mostly by medical men. Such an instrument

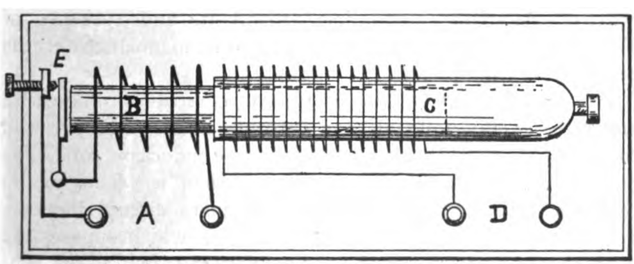


Figure 9

consists of an iron core, B, usually made up of a number of soft iron wires; and two electrical circuits insulated from each other, and terminating in the two pair of binding posts, A and D. Of these two circuits A consists of a short length of comparatively heavy wire wound upon the iron core, and is known as the *primary* coil. D is a similar coil, but usually consisting of many more turns of wire, and the wire is also of much smaller gauge and is known as the *secondary* coil.

The operation is as follows: A battery is connected to the binding posts, A, and current begins to flow in the circuit. In this circuit is an interrupter or vibrator, E, constructed similarly to the one described in connection with the electric bell. As current flows through the primary coil, it magnetizes the core, B, and this attracts the armature, E, causing it to break the connection between itself and the adjusting screw. As this connection is broken, the current in A ceases to flow, the core is de-magnetized and the armature again connects with the adjusting screw. This action is repeated just as in the electric bell, and in consequence the core B, is rapidly magnetized and de-magnetized.

Every time the core, B, is magnetized a current of electricity, lasting, however, only an instant, is induced in the secondary coil, D. The magnetism in the core is caused by a current of electricity circulating around it, and currents of electricity are in turn produced by this magnetism in the other or secondary coil.

This method of producing electric currents is known as electro-magnetic induction, and currents so produced are said to be "induced" currents, hence the name induction coil. The currents so induced are alternating, that is, changing in direction. At the "making" of the primary circuit, the current in the secondary coil is in a direction which opposes the magnetization of the core by the primary current; at the time of "break" in the primary circuit, the induced current will be in the opposite direction.

The tube, C, is movable and may be slipped entirely in over the iron core, or withdrawn entirely. If it is in, the currents which were before being induced in the secondary wires are now induced in the metal of the tube and consequently the effect on the secondaries is very much reduced.

The energy in the primary and secondary coils is always equal. If the two coils have the same number of turns, the currents and electro-motive forces are exactly alike. If the secondary coil has more turns of wire than the primary, the induced E. M. F. in it will be greater, but the current will be smaller and vice versa. The induction coil is very similar to the alternating current transformer, the main difference being that the transformer does not have an interrupter since the current supplied to it is itself constantly alternating.

Batteries.

Currents of electricity for commercial purposes are produced either by dynamo electric machines or by batteries.

A "battery" is the name given to a number of cells connected together so as to produce a current greater than one

Figure 10

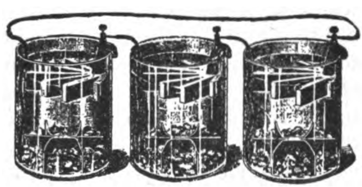


Figure 11

cell alone could produce. Figure 10 shows one cell of a kind that is generally used only intermittently, as for instance with door-bells. When the bell is not ringing the battery is idle.

This style of cell is very useful for such work, but entirely useless for work requiring current continuously. The cell consists of a glass jar which is filled about ¾ full of water in which a quantity of sal-ammoniac is dissolved. Immersed in this solution is a carbon cup or center, which forms the positive or + pole of the cell, and a zinc rod, carefully separated from the carbon by a rubber washer at the bottom and a porcelain tube at the top. So arranged, the current tends to flow, in the battery, from the zinc to the carbon and if the zinc and carbon outside of the cell be joined by a piece of wire or other conductor of electricity, the current will flow in the external circuit, from the carbon back to the zinc. If the zinc and carbon are not joined by a conductor of electricity there will be no current flow, but merely an electrical pressure tending to send a current. Each cell of this kind has an electro-motive force of about 1.4 volts. This is not sufficient for general use in connection with bells, etc., and in order to obtain greater current strength a number of cells are connected together in series as shown in Figure 11.

This figure shows a different kind of cell, but will nevertheless illustrate the method of connecting cells in series; which is, to connect the carbon or copper pole of the first cell to the zinc of the second, and again the carbon pole of the second to the zinc of the third, continuing in this way through all of the cells. Thus connected, all of the electro-motive forces act in one direction and if we have twelve cells each of an electro-motive force of 1.4 volts, we obtain a total electro-motive force to apply on our work of 12×1.4 or 16.8 volts.

Should we, however, connect six of the twelve cells as above, and then accidentally connect the other six in the opposite direction, that is, the zinc of the sixth cell to the zinc of the seventh, and then continue in this order, we should obtain no current whatever; six of our cells would tend to send current in one direction and six in the other, so that the result would be nothing. Should ten cells be properly connected to send current in one direction and two connected to oppose them, the net electro-motive force would be 10×1.4 minus 2×1.4, which is 11.2. The ten cells would force current through the other two in the opposite direction.

The electro-motive force of a cell is independent of its size, that is, a very small cell would set up just as high an electrical pressure as a very large one made of the same material. A large cell is, however, capable of delivering a much stronger current because its own resistance to the current flow is much less than that of a small cell. Large cells will, therefore, in most cases give very much better service than small ones. Especially in cases where considerable current is required as in electric gas-lighting and annunciator work, where it is always possible that two or three bells or fixtures may be called into action at the same time.

In setting up and maintaining sal-ammoniac batteries, the following general rules should be observed:

Use only as much sal-ammoniac as will readily be dissolved; if any settles at the bottom it shows that too much has been used. Keep your battery in a cool place, but do not allow it to freeze. See that the jars are always about ¾ full of water.

Keep the tops of glass jars covered with paraffin to prevent salts from creeping.

The battery should never be allowed to remain in action (i. e., send current) continuously, or it will run down. If it has been run down through a short circuit or other cause, it should be left in open circuit for several hours; it will then usually "pick up" again.

The so-called dry-batteries are made up of about the same material, but applied in form of a paste. They are suitable for the same kind of work and especially handy for portable use.

For continuous current work, such as telegraphy, for instance, the kind of battery shown in Figure 11 is generally used. The electro-motive force of this style of battery is a little less than that of the sal-ammoniac battery and its resistance is considerably greater.

Therefore, it is not well adapted for work requiring considerable current strength. Bells, telegraph instruments, etc., to be used with this battery require to be specially designed for it; the current being less in quantity must be made to circulate around the magnets many more times in order to fully magnetize them.

The sal-ammoniac batteries cannot be used continually or they will run down; this battery must be kept at work always or it will deteriorate.

This style of cell is known as the crow-foot or gravity cell, the action of gravity being depended upon to separate the essential elements of the solution.

To set up this battery, the zinc crow-foot is suspended from the top of the glass jar as shown. The other element of the cell consists of copper strips riveted together and connected to a rubber-covered wire shown at the left of each cell, Figure 11. This copper is spread out on the bottom of the jar and clear water poured in until it covers the zinc. Next drop in small lumps of blue vitriol, about six or eight ounces to each cell.

The resistance may be reduced and the battery be made immediately available by drawing about half a pint of the upper solution from a battery already in use and pouring it into the jar; or, when this cannot be done, by putting into the liquid four or five ounces of pulverized sulphate of zinc.

Blue vitriol should be dropped into the jar as it is consumed, care being taken that it goes to the bottom. The need of the blue vitriol is shown by the fading of the blue color, which should be kept as high as the top of the copper, but should never reach the zinc.

A battery of this kind when newly set up should be short circuited for a few hours, that is, a wire should be connected from the zinc at one end of the battery to the copper at the other.

There are many styles of batteries and different chemicals are used with them. The two kinds above described are, however, the most used. The methods of connecting is in all batteries the same.

Figure 12 shows a diagram of a battery connected in series; the long thin lines represent the copper or carbon pole from which the current flows in the external circuit and the short thick lines represent the zinc from which the current flows toward the copper inside of the cell.

Figure 12

If we have a circuit of low resistance to work through and desire to increase the current, we may group our cells as shown in Figure 13, where two sets are in parallel. This arrangement will give a stronger current, but it is necessary to see that both groups of cells have the same electro-motive force; if they have not, the higher one will send the current through the lower. If the two batteries are not connected with similar poles together, they would be on short circuit, and no current could be obtained in the external circuit.

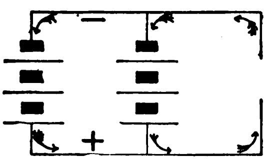


Figure 13

CHAPTER III.

Wiring Systems.

There are numerous systems of electric light distribution. The oldest and the first to come into general use is shown diagramatically in Figure 14. This is the series arc system. In this system the same current passes through all of the lamps; and as more or less lamps are required the E. M. F. of the dynamo must be correspondingly increased or diminished. This is accomplished by means of an automatic regulator connected to the dynamo.

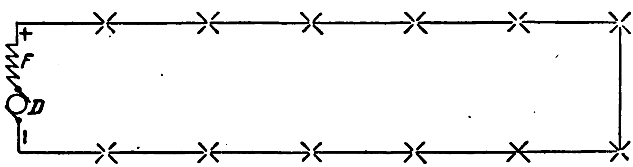


Figure 14

The current used with this system seldom exceeds ten amperes and large wires are never required. This system is best suited for street lighting where long distances are to be covered.

In these diagrams, D represents the dynamo, and F, the "field" coils of the dynamo. With *constant current* systems the "fields" are usually in series with the armature of the dynamo, as shown in Fig. 14, and the lamps, so that the same current must pass through all. With *constant* *potential* systems, the field coils are generally independent of the rest of the circuit. With such systems the current used in the circuit is so variable that it cannot be used in the fields.

Another system, known as the multiple arc or parallel system, is shown in Figure 15. In this system the E. M. F. never varies, but the current is always proportional to the

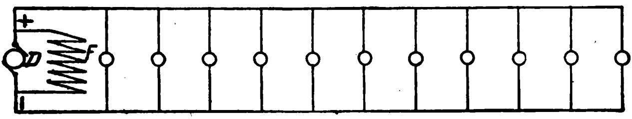


Figure 15

number of lights used. If, for instance, only one light is used, there is a current of about one-half ampere, but if ten 16 cp. lights are used there must be a current of about five amperes. Where many lights are used with this system, the main wires require to be quite large, and must always be proportional to the number of lights. This system is operated usually at 110 volts and is suitable for residences, stores, factories and all indoor illumination. It is not well adapted to the transmission of light and power over long distances.

The 3-wire system shown in Figure 16 combines many of

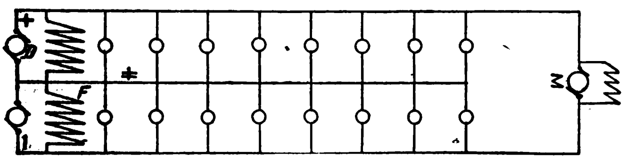


Figure 16

the advantages of both the foregoing systems. As will be seen from the diagram, it consists of two dynamos connected in series and a system of wiring of one positive +, one negative — and a neutral = wire. So long as an equal number of lights are burning on both sides of the neutral wire, this wire carries no current, but should more lights be in use on one side of the system than on the other, the neutral wire will be called upon to carry the difference. If all the lights on one side are out, the dynamo on that side will be running idle.

The currents in the neutral wire may be either positive or negative in direction. The principal advantage of this system is that with it double the voltage of the 2-wire systems is employed and yet the voltage at any lamp is no greater than with the use of two wires. It is customary to use 110 volts on each side of the neutral wire and this gives a total voltage over the two outside wires of 220 volts. As the same current passes ordinarily through two lamps in series, we need, for a given number of lamps only half as much current as with 2-wire systems and can, therefore, use smaller wires. For the same number of lights and the same per-

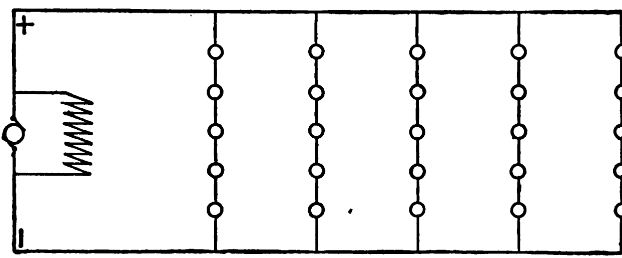


Figure 17

centage of loss the amount of copper required in the two outside wires is only one-fourth that of 2-wire systems; to this must be added a third wire of equal size for the neutral, so that the total amount of copper required with this system is 3/8 of that of 2-wire system using the same kind of lamps.

Incandescent lamps are often run in multiple-series, as in

Figure 17, without a neutral wire. The number of lamps to be used in series depends upon the voltage of the dynamo. If that is 550, five 110 volt lamps are required in each group, or ten 55 volt lamps.

If the filament of one lamp breaks all of the lamps in

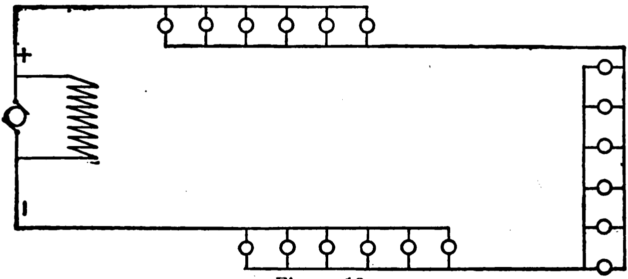


Figure 18

that group are extinguished and if one is to be used all must be used.

Figure 18 shows the diagram of a series-multiple system. This style of wiring should be avoided.

A diagram of an alternating current system is shown in

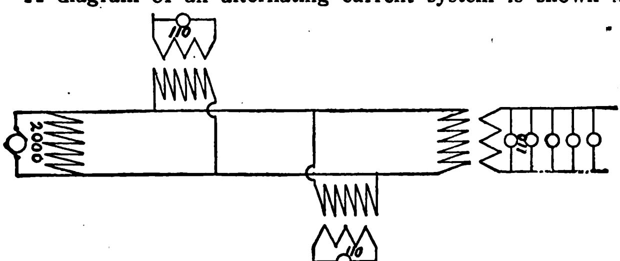


Figure 19

Figure 19. In this system extremely high voltage is used and consequently the currents are never very great. This makes

it extremely useful for long distance transmission. Since, however, the high pressure employed cannot be used directly in our lamps it must be transformed into lower pressure. This is done by means of transformers, and it is possible to reduce the line voltage to any desirable extent. As the voltage is reduced, however, the current increases and the wires taken from the transformers into the buildings must be as large as those for 2-wire systems using the same kind of lamps. The high pressure, or primary wires, are rarely allowed inside of buildings.

The Transmission of Electrical Energy.

We have seen that currents of electricity flow only in electrical conductors, and that these conductors are usually arranged in the form of wires. We have further seen that the power transmitted is proportional to the product of the volts and amperes used. The actual amount of energy transmitted being the product of the above multiplied by the time.

Currents of electricity always encounter some resistance and in consequence of this resistance, generate heat; the generation of heat in any electric circuit being proportional to the square of the current multiplied by the resistance. This formula, $I^2 \times R$ expresses the loss of electrical energy due to the resistance of the conductors and which reappears in the form of heat. If this loss is not kept within reasonable limits, the wires will become very hot and destroy the insulation or ignite surrounding inflammable material. The above loss and hazard is generally guarded against by insurance companies and inspection boards by designation of the current in amperes which certain wires may be allowed to carry.

Table No. 1 gives the currents which the National Board of Fire Underwriters has decided to consider safe and which should be closely followed, and on no account should wires smaller than those indicated be used. There is no harm and no objection to using wires larger than indicated, but neither is there much gained unless the run be a long one as we shall see further on.

The table of carrying capacities shows a great discrepancy between the relative cross-section of large and small wires and the currents they are allowed to carry; thus a No. 0000 wire has a cross-section about eight times as great as that of No. 6, yet is allowed to carry less than five times as much.

This discrepancy arises from the different rate of heat radiation. The radiating surface or circumference of a small circle or wire is relatively to its cross-section much greater than that of a large circle, and other things being equal the ratio existing between the heat given to a body and its radiating surface determine its temperature.

We have seen before that the power (either for lights or motors) consists of two factors; current and pressure, expressed respectively as amperes and volts. We have also seen that the power (watts) equals the product of these two; hence it follows, that as we increase either one, we may decrease the other, or conversely, as one is decreased the other must be increased in order to deliver a given amount of power. We further know that it is the current alone which heats the wires and that accordingly as our currents are large or small, the wires used to transmit them must be large or small. It is obvious, therefore, that we can save much on copper by using higher voltages, since, if we double the voltage, we shall need only one-half as much current and can, therefore, use a much smaller wire. As an example: Suppose we have power to transmit which at 110 volts requires 90 amperes. This requires a No. 2 wire containing 66,370 circular mils. Now, if we double the voltage, we shall need only 45 amperes; this much we are allowed to transmit over a No. 6 wire which has only 26,250 circular mils. We must not, however, increase our voltage without due precaution and consideration, for high voltage is dangerous to life and increases the fire hazard. It also increases the liability to leakage and requires better and more expensive insulation which in a small measure offsets the other advantages. The usual voltage employed at present varies from 110 to 220 volts for indoor lighting and power; 500 to 650 volts for street railway work and from 2 to 20,000 volts for long distance transmission. The higher voltages mentioned are seldom brought into buildings, and are nearly always used with some transforming device which reduces the pressure to 110 or 220 volts for indoor lighting or power.

The flow of current through a given lamp, motor, or resistance determines the light, power or heat obtainable from such device. We know that the flow of current in turn (other things being equal) varies as the E. M. F. maintained at the terminals of any of these devices. Consequently in order to obtain a steady flow of current it is necessary to provide a steady E. M. F.

The loss of E. M. F. in any wire is equal to the current flowing in that wire multiplied by the resistance of the wire. Since it is impossible to obtain wires without resistance, it is also impossible to establish a circuit without loss and wherever electricity is used some loss must be reckoned with. We may make this loss as large or as small as we desire. Where the cost of fuel is high, it is important to keep this loss quite small, using for that purpose larger wires. On the other hand where there is an abundance of cheap fuel, or, where, for instance, water power is used, it will be more economical to waste five or ten per cent of the electrical energy than to spend the money needed to provide the copper necessary to reduce the waste to one or two per cent.

In this connection, however, it must not be overlooked that the quality of the service depends to a great extent upon the loss allowed and here the nature of the business supplied must be taken into consideration. In yards, warehouses, barns, etc., a variation of five or ten per cent in candle power may not matter much, but in residences or offices it is very annoying.

The loss in voltage depends, as we have already seen, upon the current used, and the resistance of the wire employed. If the current is decided upon, we can reduce the loss only by reducing the resistance; the resistance can be reduced only by increasing the size of wire used. If we double the cross-section of the wire, we decrease the resistance one-half and consequently reduce the loss or variation in voltage one-half. Thus it will be seen that as we attempt to reduce the loss in voltage to a minimum we shall require very large wires and thus greatly increase the cost of our installation.

For instance, if a line be in operation with a loss of twenty per cent, by doubling the amount of copper, we reduce the loss to ten per cent. In order to reduce our loss to five per cent, we must again double the amount of copper; and to reduce the loss still more, say to 2½ per cent, a wire of double the cross-section of the last must be used. If the cost of copper in the original installation utilizing eighty per cent of the energy be taken as 1, then the cost of copper to utilize ninety per cent will be 2; of ninety-five per cent, 4; and of ninety-seven and one-half per cent, 8; and no amount of copper will ever be able to save the full 100 per cent. We must not overlook, however, that although a reduction of loss from four to two per cent requires us to double the amount of copper, it does not necessarily double the cost of our installation, for in many cases it adds but a small percentage to the total cost. For instance, if it were decided to use No. 12 instead of No. 14 wire in moulding or insulator work, the cost of labor would not be appreciably affected thereby; similarily in connection with a pole line, the difference in total cost occasioned by the use of say No. 6 instead of No. 10 wire would be small.

Calculation of Wires.

In electrical calculations so far as they relate to wiring, the *circular mil* plays an important part, and it becomes necessary to thoroughly understand its meaning. The mil is the 1/1000 part of an inch, consequently one square inch contains 1,000x1,000 equals 1,000,000 *square mils.* If all electrical conductors were made in rectangular form, we should be able to get along nicely by the use of the square mil, but, since they are nearly all in circular form, the use of the square mil as a unit would necessitate otherwise unnecessary figures. The *circular mil* means the cross-section of a circle one mil in diameter, whereas the *square mil* means a square each side of which is equal to one mil in length. Square mils, can, therefore, be transformed into circular mils by dividing by .7854, and circular mils into square mils by multiplying by .7854, since it is well known that a circle which can be inscribed within a square bears to that square the ratio of .7854 to 1.

To illustrate: Using square mils if we wish to determine the cross-section of a wire having a diameter of 50 mils, we must first square the diameter and then multiply by .7854; 50 × 50 × .7854, or 1963.5, which is the cross section of the wire expressed in square mils. To express the cross-section in circular mils, we have but to square the diameter, or 50 × 50 = 2500 circular mils. The 2500 circular mils are exactly equal to the 1963.5 square mils. The adoption of the circular mil simply eliminates the figure .7854 from the calculations.

The resistance of a copper wire having a cross-section of one mil and a length of one foot is from 10.7 to 10.8 ohms, the variation being due to the temperature of the wire. 10.8 ohms is the resistance usually taken. This resistance increases directly as the length and decreases as the cross-section increases. The resistance of any copper wire can, therefore, be found by multiplying its length by 10.8 and dividing by the number of circular mils it contains. Expressed in formula this becomes $R = \frac{L \times 10.8}{C.\ M.}$ where L stands for the total length of wire in feet, and C. M. for the cross-section in circular mils, and R for the resistance in ohms. In order to find the loss in volts, we must multiply the resistance by the current used. Representing this current by I, the formula becomes $\frac{I \times L \times 10.8}{C.\ M.} = V$; V being the volts lost.

It is, however, seldom necessary to find how many volts would be lost with a certain wire and current, but rather to find how many circular mils are necessary in a wire so that the volts lost may not exceed a certain percentage. In order to determine this, we transpose V and C. M. and the formula now becomes $\frac{I \times L \times 10.8}{V} = C.\ M.$ This is the final formula and gives directly the number of circular mils a wire must have so that the loss with this current and length of wire shall not exceed the limits set by V.

As an example, we have a current of 20 amperes to transmit a distance of 200 feet and the loss shall not exceed two per cent; voltage 110. This requires 400 feet of wire (two wires 200 feet long) and two per cent of 110 is 2.2. We therefore have 20 × 400 × 10.8 divided by 2.2, which gives us 39,270 circular mils, which we see by table I is a little less than a No. 4 wire.

The above formula will answer for all 2-wire work, whether it be lights or power.

It is simply necessary to find the current required with whatever devices are to be used.

These calculations are not often made in actual practice. It is much easier to refer to tables such as II. III, IV, V, VI, given at the end of this volume, by which the proper size of wire can be determined at a glance almost.

In connection with 3-wire systems using two lamps in series, we need to calculate the two outside wires only, the neutral wire should then be taken of the same size. We must however assume double the voltage existing on either side of the neutral; that is to say, a 2-wire system using 110 volts would be figured at 110 volts, while a 3-wire system, using 110 volt lamps on each side of the neutral wire would be figured at 220 volts.

It must also be noted that with 3-wire systems the current required is only ½ of that required with 2-wire systems. Ordinarily we have two lamps in series and the same current passes through both. Applying this to our formula we see that with the 3-wire system the current I is only half as great as with 2-wire systems and (the percentage of loss in both cases being the same) V, which stands for the volts to be lost, becomes twice as great. Owing to these two factors, the wire for 3-wire systems need have only ¼ as many circular mils as that of a 2-wire system with the same percentage of loss. To this must be added the neutral wire so that the total cost of wire must be ⅜ of that for the 2-wire systems.

The amount of copper required in power transmission for a given percentage of loss varies as the square of the voltage employed. By doubling the voltage we can transmit power with the same loss four times as far; or, if we do not change distance or wire, we shall have only one-fourth of the loss we had before. A practical idea of the laws governing the distribution of circuits and the losses in voltage and wire which are unavoidable may be gained from Figure 20.

Figure 20 shows 96 incandescent lights arranged on one floor and placed 10 feet apart each way. With all cutouts placed at A and circuits arranged as in No. 1, 2,080 feet of branch wiring for the eight circuits of 12 lights each, will be required. If the cutouts be placed in the center, B, the same length of wire will be necessary. We have in this case merely transferred the cross wires from one end of the hall to the center. If we arrange two sets of cutouts as at C and D and run circuits as 3 and 4 the total amount of wire necessary will be only 1,920 feet. By this arrangement we avoid the necessity of crossing the space indicated by dotted lines at the right, opposite B.

If we run the circuits on the plan of No. 2, the least amount of wire for the eight circuits will be 2,560 ft. Such wiring would require extra wires feeding the various groups. Should we run a set of mains along ACBD, and make 12 circuits of the installation by placing one cutout for each eight lights, the amount of wire required will be 1,680 feet. If we run a set of mains through B as shown by dotted lines using 12 lights per circuit, 1,760 feet of wire will be required. If we now double the number of lights in the same space or limit the number per circuit to six, we shall require 3,200 feet of wire to feed them all from A, but only 2,400 to feed them from B; to feed them all from the two centers C and D will also require 2,400 feet.

The most economical location of cutout centers will, with even distribution of light, and in regard to branch wiring only, be such that it is unnecessary to run circuits like No. 2; in other words, not more than the number of lights allowed on one circuit should lead away from it in one direction.

Suppose, for instance, the number of lights be increased

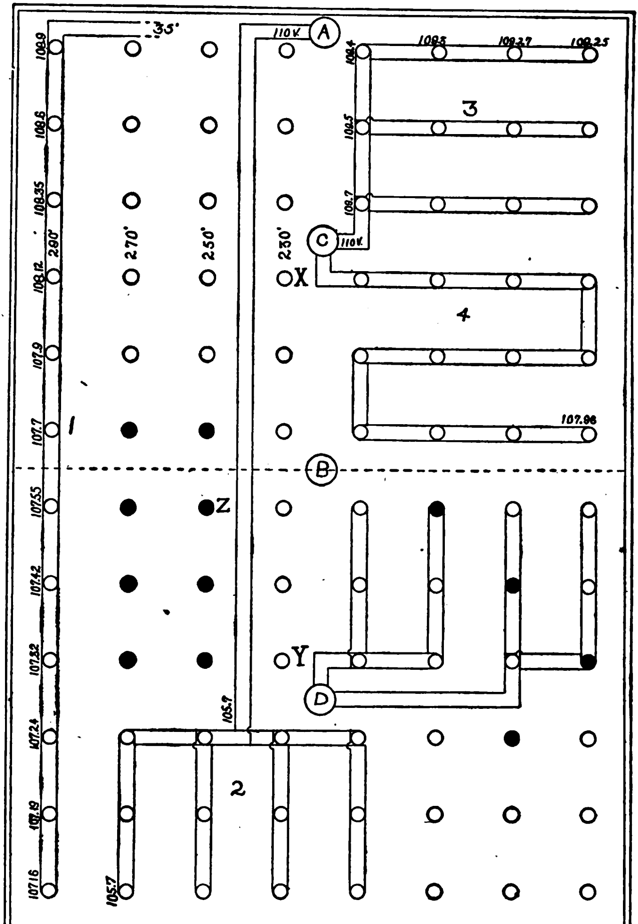

35'
110V.
A
108.9
108.6
108.35
290'
108.12
107.9
107.7
107.55
107.42
107.32
107.24
107.19
107.16
270'
250'
230'
X
1
B
Z
Y
D
105.7
105.7
2
108.4
108.5
108.7
C
110V.
3
4
107.96

Figure 20

by one-half or (which amounts to the same thing in wire), the number of lights per circuit be limited to eight. If we run all branch circuits from A, we shall need a total of 2,760 feet. It will require just as much wire to run the 64 lights below X as was required to run the whole 96 before; viz.: 2,080 feet; to this must be added the wire necessary to run the four circuits above which is 680 feet. By extending our mains to the point X, we can save eight runs of wire each equal in length to the distance between A and X. X is the point of extreme economy as regards branch wires and nothing can be gained in this respect by extending the mains any further unless several cutout centers are decided upon as before explained. Whether it be more economical to extend the mains to X, or run branch circuits from A, depends upon the relative cost, in this instance, of 30 feet of mains and 480 feet of branch wires.

With an uneven distribution of lights as indicated by the black circles, each of which may be taken as an arc lamp or cluster of incandescent lamps, the most economical location of cutouts will be at Z. To move them farther to the right would shorten the wires of five circuits and lengthen them on eight; to move either up or down in the group of eight would also lenghten more wires than it would shorten.

In laying out circuits for electric lights, however, we must not take into consideration the cost of wire only. In many cases the loss in voltage is of far greater importance, not only because it means a steady waste of power, but also because of unsatisfactory illumination, lamps in different parts of a circuit not being of the same candle power, or the light in one place varying greatly when lights in another place are turned on or off.

Some idea of the variation in voltage in different parts of differently arranged circuits can be obtained from Figure 20. The length of wire in circuit 1 is 35 feet to the first lamp and

10 feet from this to the next, etc. The voltage at the cutout A is 110 and at each lamp is given the actual voltage existing at that point with all lamps burning. The wire of the circuit is No. 14 and with 55 watt lamps, the loss to the last lamp over a run of 145 feet is a trifle over two and one-half per cent when all lamps are burning.

Circuit No. 2 is figured as of the same length as No. 1, and supplies the same number of lamps, but at a much greater loss, slightly over four per cent to the last lamp. Circuits 3 and 4 feeding from C contain equal lengths of wire, but there is quite a difference in loss; in 3 only .75 of one volt, while in 4 it is a little over two volts. From study of Figure 20 we may learn that the arrangement of circuit 1 is fairly satisfactory especially if the nature of the work done under it is such that only part of the lamps are used at the same time. Circuit No. 2 is bad if all lights are used at once, and it should be wired with No. 10 or 12 wire. Whenever the location of lights is such as to allow a circuit like No. 3 to be run, the loss can be kept very low with a minimum of wire. In general the more cutout centers there are established in proportion to the number of lights, if mains are properly arranged, the less will be the loss in pressure and the more satisfactory the service.

NOTICE.—DO NOT FAIL TO SEE WHETHER ANY RULE OR ORDINANCE OF YOUR CITY CONFLICTS WITH THESE RULES.

CLASS A.

STATIONS AND DYNAMO ROOMS.

Includes Central Stations, Dynamo, Motor and Storage-Battery Rooms, Transformer Substations, Etc.

1. Generators.

a. Must be located in a dry place.

It is suggested that water proof covers be provided, which may be used in case of emergency.

Perfect insulation in electrical apparatus requires that the material used for insulation be kept dry. While in the construction of generators the greatest care is taken that all current carrying parts are well insulated, still, if moisture is allowed to settle on the insulation, trouble is almost sure to occur. For this reason a generator should never be installed where it will be exposed to steam or damp air or in any place where through accident water may be thrown against it. A location under steam or water pipes or close to an outside window should be avoided.

b. Must never be placed in a room where any hazardous process is carried on, nor in places where they would be exposed to inflammable gases or flyings of combustible materials.

In even the best constructed dynamos there is alyays more or less sparking at the brushes and small pieces of hot carbon are sometimes thrown off. As a general rule in buildings where there is considerable dust, such as in wood-working plants, grain elevators and the like, the dynamo is located in the engine room, which is generally isolated from the dusty part of the building.

c. Must, when operating at a potential in excess of 550 volts, have their base frames permanently and effectively grounded.

Must, when operating at a potential of 550 volts or less, be thoroughly insulated from the ground wherever feasible. Wooden base frames used for this purpose, and wooden floors which are depended upon for insulation where, for any reason, it is necessary to omit the base frames, must be kept filled to prevent absorption of moisture and must be kept clean and dry.

Where frame insulation is impracticable, the Inspection Department having jurisdiction may, in writing, permit its omission, in which case the frame must be permanently and effectively grounded.

If desired, high potential machines may be surrounded by an insulated platform, made of wood, mounted on insulating supports, and so arranged that a man must always stand upon it in order to touch any part of the machine.

Under ordinary circumstances it is better to insulate the base frames of generators. Excessive voltages are often produced in the windings, as for instance, where the field circuits are opened, and unusual electrical strains result. A generator with an insulated base frame is, therefore, less liable to trouble from grounds than one in which the base frame is in electrical connection with the ground.

Where generators operate at high voltages, however, the question of life hazard must be considered. If the base frame is insulated from the ground there is always the possibility that a person touching it may receive a severe shock and for this reason it is deemed advisable to ground all generator frames where the voltage generated is over 550 volts.

The smaller generators are usually insulated on wooden base frames. A base frame suitable for this work is shown in Figure 21. Almost any kind of wood, well varnished, is very good for this purpose. The base frame is screwed to the floor or foundation and the slide rail (which is used where the dynamo is belted to the engine to allow the tightening and slackening of the belt) is independently attached to it, that is, the same bolt must not be used to hold the slide rail to the

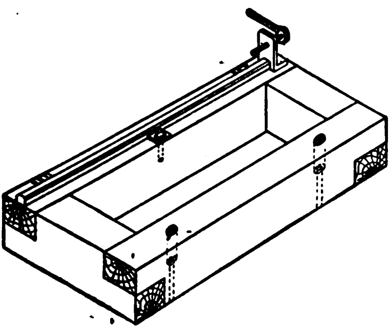


Figure 21.

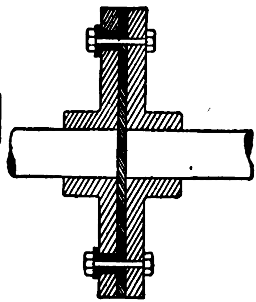


Figure 22.

base frame and the base frame to the floor, as this would be liable to ground the frame. The direct connected machines (dynamo and engine on same bed plate) are often insulated by the use of mica washers and bushings surrounding the bolts which fasten the dynamo to the bed plate and by using an insulated flange coupling between the shaft of the dynamo and that of the engine. Figure 22 shows a section of a flange coupling insulated in this way, the heavily shaded parts representing the insulating material.

The larger machines, which on account of their weight cannot be insulated, must be permanently and effectually grounded. Where the engine and dynamo are direct connected a very good ground is obtained through the engine connections. Where belts are used a good ground can be obtained by fastening a copper wire under one of the bolts on the dynamo and connecting the other end of the wire to available water pipes.

In the case of high tension machines, especially series arc, the machine should always be surrounded by an insulated platform so arranged that a man must stand on it in order to

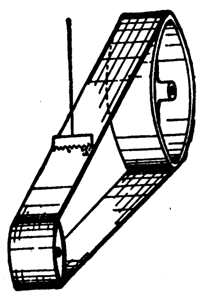


Figure 23.

touch any part of the machine, either live parts or frame, and in handling such a machine only one hand at a time should be used. A hardwood platform mounted on insulators will serve very well for this purpose or suitable platforms may be obtained from dealers in electrical supplies.

Figure 23 shows a metallic comb such as is occasionally used to overcome the static electricity due to the friction of the belt. A strip of metal, one end of which is cut with a number of projecting points, is suspended crosswise a short distance above the belt. A wire connects this plate to any suitable ground.

A resistance for grounding the generator frame in accordance with this rule is constructed of ground glass equipped with two metal terminals separated a short distance and connected by means of a lead pencil mark. One terminal is connected to the frame of the machine and the other to the ground.

d. Constant potential generators, except alternating current machines and their exciters, must be protected from excessive current by safety fuses or equivalent devices of *approved* design.

For two-wire, direct-current generators, single pole protection will be considered as satisfying the above rule, provided the safety device is located in the lead not connected to the series winding. When supplying three-wire systems, the generators must be so arranged that these protective devices will come in the outside leads.

For three-wire, direct-current generators, a safety device must be placed in each armature, direct-current lead, or a double pole, double trip circuit breaker in each outside generator lead and corresponding equalizer connection.

Constant potential generators are designed to carry a certain amount of current without seriously overheating. If any considerable overload is put on a machine of this type a dangerous rise in the temperature of the generator and the wires connected to it will occur and a fire may result. To protect the apparatus some safety device must be installed in the main circuit which will cut off the current when it exceeds its normal maximum value. The safety fuse is commonly used for this purpose, but circuit breakers of approved design meet the requirements of the rule and may be used in place of the fuses.

Alternating current generators are usally constructed in large units. If a safety device installed in the main circuit of one of these large machines should operate and open the circuit, the generating apparatus, dynamo and engine would momentarily be left in a dangerous condition owing to the fact of the load being suddenly removed from the generator.

The sudden disrupting of the circuit of an alternating current generator gives rise to a momentary, excessive increase in the E. M. F., and as this is usually already very high there is great tendency to pierce the insulation of the generator winding.

In view of these facts, and for the further reason that on short circuit the impedance of an alternating current armature consisting of many coils in series is generally of such an

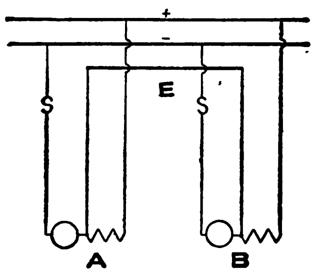


Figure 24.

amount as to limit the resultant current, alternating current generators are excepted from the general rule requiring protection by safety devices. While the rule does not require protective devices in any alternating current generator, still it is the general practice, and it is advisable, to provide fuses or circuit breakers on the smaller size generators such as are used in isolated plants for instance.

Fuses are sometimes mounted on the generator itself, but the general practice at the present time is to mount all fuses on the switchboard. For two-wire, direct current generators one fuse will suffice, provided this fuse is located in the lead which is not connected to the series winding. The diagram Figure 24 shows the proper location of the fuses. An inspection of this diagram will also show the reason for this requirement. Two compound wound generators are shown connected in parallel. To avoid confusion the shunt field and switch connections are not shown. When the generators are operating together current from the brush on the right-hand side of machine A has two paths by means of which it can get to the positive bus bar. One of these paths is through its own series field and the other through the equalizer connection

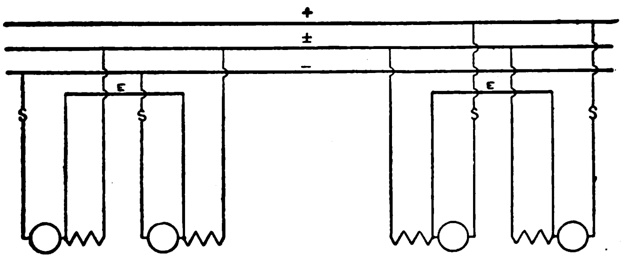


Figure 25.

and series field of generator B. The current in the lead connected to the series field may not be of as great strength as that generated in the armature; or, due to the fact that it may be receiving additional current from the other machine through the equalizer connection, it may be of greater strength than that generated in the armature. A fuse placed in this lead could not, therefore, provide proper protection for the armature.

Where a shunt wound generator is used the fuse may be placed in either lead. The same is true in the case of a single compound wound generator, for no equalizer connection is used in this case, and the current in both leads is always the same.

Where generators are feeding a three-wire system the fuses should be placed in those leads which feed into the positive and negative mains, Figure 25. They should not be placed in the equalizer lead or in the lead connected to the series field for the reasons already given. It will be noticed that the two generators shown at the right of the diagram are connected in a reverse manner from those at the left. An examination of the diagram, Figure 26, will show the reason for

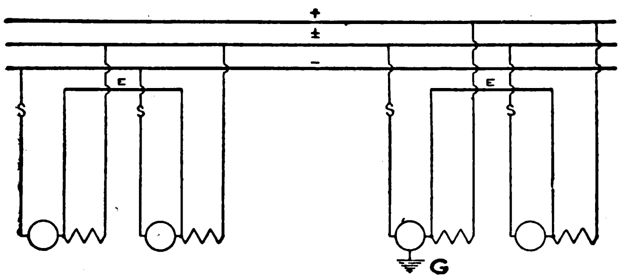


Figure 26.

this. In this case the placing of the fuse in the lead not affected by the equalizer current brings it in the lead connected to the neutral bus. If, with the fuse located in this line, the generator winding should become grounded a short circuit would result, as the neutral wire is always grounded, current flowing from the positive bus bar through the positive lead and the wires on the generator to the ground. The generator would have absolutely no protection in a case of this kind and a fire would be sure to result. If the fuses were placed in the outside leads the circuits would be immediately opened and current shut off from the machine.

Figures 27, 28 and 29 show the proper location of fuses in three-wire, direct current generator installations. In Figure 27 is shown the wiring connection of a three-wire direct current generator. The armature of this generator contains two separate armature windings, each winding being provided with its own commutator, located on each side of the armature. Two separate series field windings are provided, each

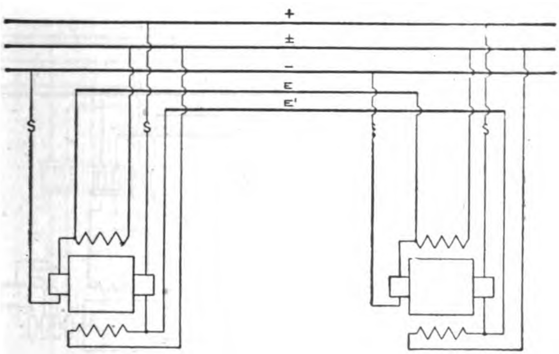


Figure 27.

field winding being connected in series with an armature winding. The shunt field connections are not shown.

To comply with the requirements each generator should be connected to the bus bars and fuses installed as shown. The simplified diagram, Figure 30, shows the reason for this arrangement. Referring to the connections shown it will be seen that the fuses protect each armature winding both from overload or from possible shorts caused by the grounding of the armature windings. A wrong arrangement of the fuses, and one that should be avoided, is shown in the diagram, Figure 31. In this case fuses are installed in the lead from the series winding. The first objection to this arrangement is the one which has already been explained, *i. e.*, the current from the armature having two paths open to it, one through the series field and one through the equalizer, the armature could generate an excessive current without the fuse, which may be carrying only a part of the current, blowing. If for any reason one of the fuses shown did blow serious conditions might result owing to the fact that the arma-

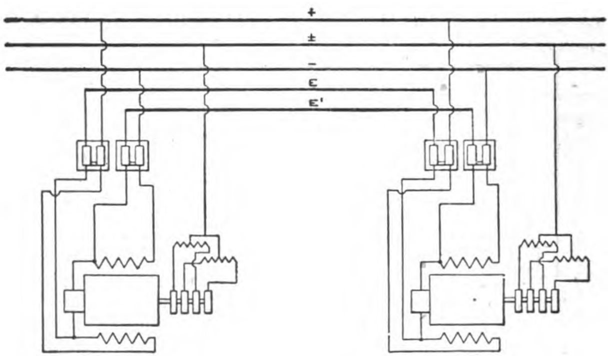


Figure 28.

ture of that machine is still connected to the armatures of all the remaining machines through the equalizer bus. A double-pole circuit breaker so arranged as to open both the series field lead and the equalizer lead would remove this objection, but, as the circuit breaker would be actuated by the current in the series field lead the objections before stated still exist. Locating the fuse in the armature lead connected to the neutral bus would leave the generator unprotected in case of grounds.

Figure 28 shows the connections of the Westinghouse direct current, three-wire generator. In this generator direct current at the potential of the outside mains, usually 220 volts, is taken off the commutator side while the neutral connection is made through auto transformers to slip rings on the opposite side of the armature shaft. Two separate series field windings are connected in series with each direct current armature lead. In order to place a fuse in each direct current armature lead, fuses would have to be mounted on the generator itself or the

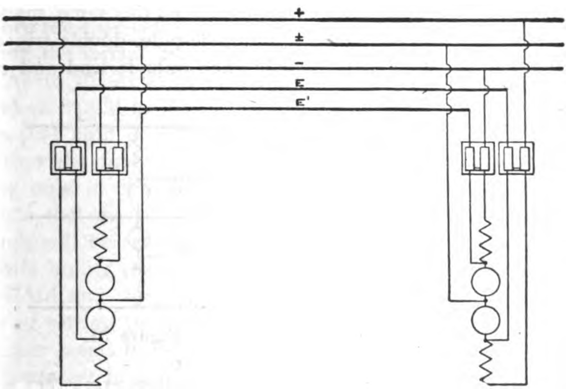


Figure 29.

leads would have to be carried from the armature brushes to the switchboard and back to the series field. The usual protection provided with this generator consists of double-pole, double-trip circuit breakers connected in the leads from the series fields and corresponding equalizer connection, this circuit breaker being actuated by the current in the lead from the series field and arranged to open both series field and equalizer leads. As this generator is designed to withstand only a 25 per cent overload the circuit breakers should be interconnected so that in case one generator lead opens it automatically opens the remaining lead.

Figure 29 shows the wiring connections of a compensator set. This set consists of two machines, the armature shafts of which are rigidly connected together. Each machine acts as a motor or generator, depending on the condition of unbalance; and they are used only to balance the system, other generators supplying current to the outside mains.

This class of apparatus is protected in the same manner as in the case just described. A double-pole, double-trip circuit breaker should be installed in each outside lead and cor-

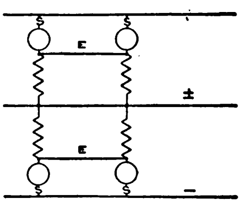


Figure 30.

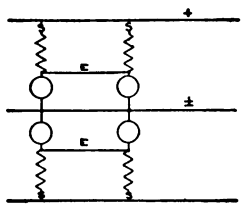


Figure 31.

responding equalizer lead. It might be well to state that with apparatus designed on the principle just described various details of construction of the machines, as built by the different manufacturers, require a more complicated system of protection so that the above rule is not always exactly complied with.

Circuit breakers, when used for protection in dynamo leads, are generally mounted on the switchboard and connected in the circuit ahead of the main switch. The circuit breaker as at present constructed is, in nearly all cases, a much more efficient and reliable device than the fuse, and its use is to be recommended. The fusing point of an ordinary fuse depends on the temperature of the fuse metal. When fuses are used in an engine room where the temperature is often very high the fuse may blow when it is carrying a current very much less than its rated capacity, and this will generally result in a larger fuse being installed. The circuit breaker is not affected by this increase in temperature. When a fuse blows from overload it generally occurs at a time when all the appartus is in use and serious delays are apt to result before the fuse can be replaced. This objection does not exist where the circuit breaker is used.

As to the relative currents at which the fuse and circuit breaker should be set to operate, authorities differ. Some advise that both be set to operate at the same current strength so that the fuse, which takes a longer time to operate, will blow only in case the circuit breaker fails. Another recommends that the fuses be of such capacity as to carry any load which will be required of them and to set the circuit breaker a little higher than the fuses so that the fuses will operate on overload and the circuit breaker on short circuit. The practice of setting the fuses at about 25 per cent above the circuit breaker seems to be preferred, for it frequently happens, when both are set to operate at the same current strength, the fuse alone will 'blow," due to the excessive heat produced in the fuse at full load.

There is a tendency in the design of some of the newer generators to do away with binding posts, leads properly bushed through the generator frame and arranged for direct connection to leads from switchboard being provided instead. As this does away with exposed, live parts it is to be recommended. Where there are exposed live parts on the generator or its connections they should be protected from accidental contact, except where they are at the same potential as the ground, as in the case of the neutrals on the direct current three-wire systems and the ground return on trolley systems.

Cases are sometimes found where the cessation of current due to the blowing of a fuse could cause more damage than would result from on overload, as, for instance, where the dynamo operates some safety device. In cases of this kind the Inspection Department having jurisdiction may modify the requirements.

e. Must each be provided with a name-plate, giving the maker's name, the capacity in volts and amperes, and the normal speed in revolutions per minute.

f. Terminal blocks when used on generators must be made of *approved* non-combustible, non-absorptive insulating material, such as slate, marble or porcelain.

g. The use of soft rubber bushings to protect the lead wires coming through the frames of generators is permitted, except when installed where oils, grease, oily vapors or other substances known to have rapid, deleterious effect on rubber, are present in such quantities and in such proximity to motor or dynamo as may cause such bushings to be liable to rapid destruction. In such cases hardwood properly filled, or preferably porcelain or micanite bushings must be used.

2. Conductors.

(For construction rules see Nos. 49 to 57.)

From generators to switchboards, rheostats or other instruments, and thence to outside lines:—

a. Must be in plain sight or readily accessible.

Wires from generator to switchboard may, however, be placed in a run-way in the brick or cement pier on which the generator stands. When protection against moisture is necessary, lead covered cable or iron conduit must be used.

b. Must have an *approved* insulating covering as called for by rules in Class "C" for similar work except that in central stations, on exposed circuits, the wire which is used must have a heavy braided, non-combustible outer covering.

Bus-bars may be made of bare metal.

Where a number of wires are brought close together, as is generally the case in dynamo rooms, especially about the switchboard, they must be surrounded with a tight, non-combustible outer cover.

Flame proofing must be stripped back on all cables a sufficient amount to give the necessary insulation distances for the voltage of the circuit on which the cable is used.

c. Must, when not in a conduit, be kept so rigidly in place that they cannot come in contact.

d. Must in all other respects be installed with the same precautions as required by rules in Class "C" for wires carrying a current of the same volume and potential.

e. In wiring switchboards, the ground detector voltmeter, pilot lights and potential transformers must be connected to a circuit of not less than No. 14 B. & S. gage wire that is protected by an *approved* fuse, this circuit is not to carry over 660 watts.

For the protection of instruments, and pilot lights on switchboards, *approved* N. E. Code Standard Enclosed Fuses are preferred, but *approved* enclosed fuses of other designs of *not over two (2) amperes capacity,* may be used.

A number of different methods are used for running wires in dynamo rooms. Where the dynamo is located in a room with a low ceiling, or where it is not desirable to run the wires open, metal conduits may be imbedded in the floor and the wires run in them. If the engine room is located in the basement or in any place where water or moisture is liable to gather on the wires, lead covered wires must be used or the wires must be run in iron conduit. It is permissible to install an ordinary braided rubber covered wire or cable without a lead covering in iron conduit, but in this case the greatest care should be taken that all joints in the conduit system are well leaded and well made so that the conduit system when installed will be water tight. In most installations the generator leads are not protected by fuses and a short circuit in them is very liable to result in a fire. The reliability of the whole plant is also dependent on the generator leads so that it is generally advisable, where moisture is present, to use lead covered wires or cables for generator leads. At outlets the conduits should be carried some distance above the floor level and close to the frame of the machine, where the wires will be protected from mechanical injury. If the space under the machine will allow it, the conduit should be ended there where it will be protected by the base frame. Where lead covered wires are used, the lead should be cut back some distance from the exposed part of the wire and the end of the lead should be well taped and compounded so that no moisture can creep in between the lead and the insulation.

In place of the metal conduits tile ducts can be used; or, if the floor is of cement, a channel may be left in the floor and the wires run into it. A removable iron cover should be provided.

The wires may be run open on knobs or cleats as described in Class C. Where there are many wires, cable racks, constructed of wood or preferably iron, having cleats bolted to them, may be used. As a general rule moulding should not be used for this class of work. Especially in central stations the generators are often called upon for a very heavy overload and should the wires become overheated a fire is much more apt to result when the leads are run in moulding than if they were run open where any trouble could be immediately noticed.

The bringing together of a number of wires, as frequently occurs in dynamo rooms, presents a distinct fire hazard unless some means is taken to protect the wires in case of fire. The rubber insulation of wires is very inflammable and a quantity of it burning, not only causes a hot fire but also produces a considerable amount of dense smoke. For the protection of rubber covered wires the outer braid may be flameproof or a non-combustible tubing may be slipped over the ordinary braided wire. If either of these is used care must be taken to strip them back some distance from the copper as they are absorbent and moisture will be sure to cause grounds.

For the wiring on the back of the switchboard slow-burning wire may be used.

3. Switchboards.

a. Must be so placed as to reduce to a minimum the danger of communicating fire to adjacent combustible material.

Switchboards must not be built up to the ceiling, a space of three feet being left, if possible, between the ceiling and the board. The space back of the board must be kept clear of rubbish and not used for storage purposes.

b. Must be made of non-combustible material or of hardwood in skeleton form, filled to prevent absorption of moisture.

If wood is used all wires and all current carrying parts of the apparatus on the switchboard must be separated therefrom by non-combustible, non-absorptive, insulating material.

c. Must be accessible from all sides when the connections are on the back, but may be placed against a brick or stone wall when the wiring is entirely on the face.

If the wiring is on the back, there must be a clear space of at least eighteen inches between the wall and the apparatus on the board, and even if the wiring is entirely on the face, it is much better to have the board set out from the wall.

d. Must be kept free from moisture.

The switchboard may be located in any suitable place in the dynamo room but never placed in close proximity to combustible material or where, if a fire did start, it would be liable to communicate to surrounding walls. It should generally be placed in a central position as close as possible, without inconvenience, to all machines and perfectly accessible. Do not locate a switchboard under or near a steam or water pipe or too close to windows, as in such locations the board may at any time become wet.

The switchboard may be made of hardwood in skeleton form (See Figure 32), but in this case all switches, cutouts, instruments, etc., must be mounted on non-combustible, nonabsorbtive, insulating bases, such as slate or marble, and all wires must be properly bushed where they pass through the wood work and must be supported on cleats or knobs. Wood base instruments are not approved.

The wood switchboard is fast becoming obsolete, modern

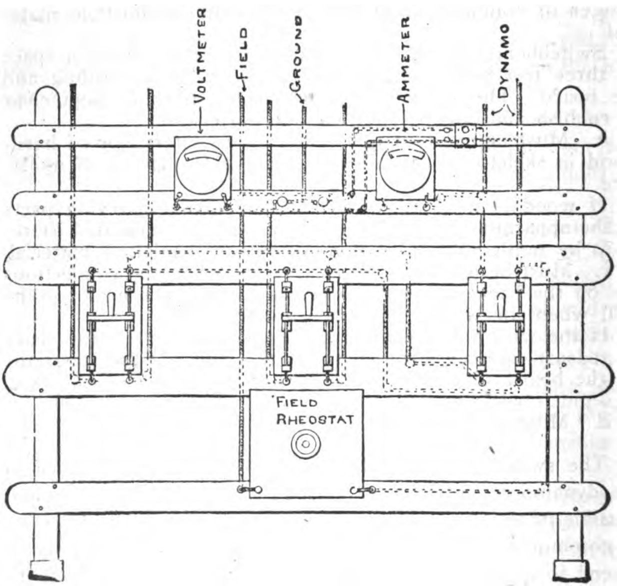


Figure 32.

switchboards being constructed of slate or marble slabs. These slabs must be free from metallic veins, for if these are present they may cause considerable leakage of current which will manifest itself by heating.

The marble or slate slab is supported in an angle iron frame so constructed as to support and substantially brace the slab. The metal frame should preferably, for low potential work, be insulated from the gound by mounting on wood or marble blocks; this, however, not being demanded by the Underwriters' rules.

The switchboards should be so arranged that all switches and other operating devices are in easy reach and the rear of the board should be free from unnecessary crossing of bus bars and other conductors. In designing a switchboard special attention should be paid to the manner in which the conductors are brought to the board and the bus bar work should be so laid out as to require the minimum amount of exposed rubber covered conductors.

It is well to keep all lights used for decorative or illuminating purposes entirely off the board as these complicate the wiring. Plenty of light should be provided both at front and rear of the board but these should be supplied by separate wiring.

Wires, or wires and bus bars, of opposite polarity should in no case come in contact and where liable to come in contact should be rigidly supported. All parts of the board should be easily accessible for inspection and repairs. A separation should be maintained between bus bars and conductors and any grounded metal part of the board. This separation should be as great as possible and in no case less than one-half inch.

Bus bars should be of ample carrying capacity. While the Code does not specify any particular carrying capacity for bus bars, this being considered more of an engineering feature as these bars are not surrounded by the usual combustible insulating material, still they should be of ample size. A bus bar that heats is liable to communicate heat to the fuses and cause them to blow below their designed capacity. Sizes and carrying capacities of bus bars commonly used are as follows:

Thickness of Bus Bar	Carrying Capacity
⅛ inch	1,000 amperes per sq. in.
¼ inch	800 amperes per sq. in.
⅜ inch	700 amperes per sq. in.
½ inch	600 amperes per sq. in.

For bolted connections between copper bus bars an area of one square inch is generally allowed for each 150 amperes.

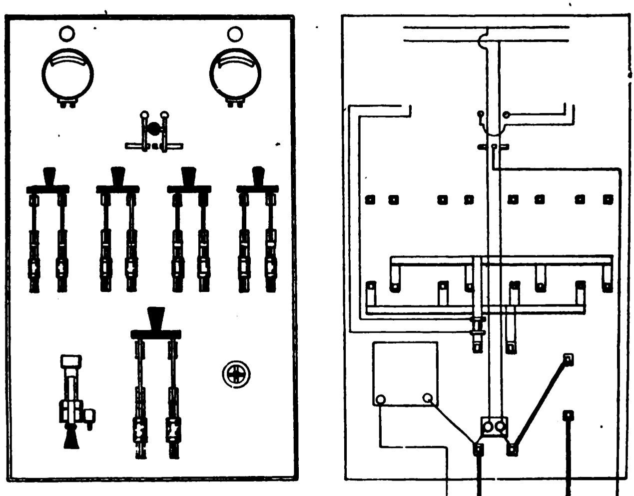


Figure 33.

This will, however, vary with different manufacturers from 100 to 200 amperes per square inch.

The code calls for a minimum spacing of 18 inch between the apparatus on the back of the board and the wall. This is often misinterpreted to apply to the marble slab and not to the apparatus on the back of the board, with the result that there is little or no free space at the back of the board when the bus bars and other apparatus is put in place. It is of the utmost importance for the personal safety of any one who has to work at the back of the board, especially when the board is alive, that sufficient space be provided and at least three feet should always be allowed where possible.

As there is a great temptation to use the space back of the board for storage purposes it is quite common practice to provide an iron grating surrounding the board and to place locks on the doors so that access can be obtained only by those authorized.

Figure 33 shows the front and rear views of a modern switchboard.

4. Resistance Boxes and Equalizers.

(For construction rules see Nos. 78 and 79.)

a. Must be placed on a switchboard, or at a distance of at least one foot from combustible material or separated therefrom by a slab or panel of non-combustible, non-absorptive, insulating material such as slate, soapstone or marble, somewhat larger than the rheostat, which must be secured in position independently of the rheostat supports. Bolts for supporting the rheostat shall be countersunk at least one-eighth inch below the surface at the back of the slab and filled. For proper mechanical strength, slab should be of a thickness consistent with the size and weight of the rheostat, and in no case to be less than one-half inch.

If resistance devices are installed in rooms where dust or combustible flyings would be liable to accumulate on them, they must be equipped with dust-proof face plates.

Resistance boxes or rheostats are used for a great variety of purposes in electrical work. The Code is concerned mostly with that class of resistance box used with light or power work where more or less heat is developed. The more common uses of resistance boxes are given below and in each of these cases the device must be installed in accordance with the foregoing rules: starting boxes for motors, speed controllers for motors including elevator starters and the like, field rheostats for both motors and dynamos, resistances used in series with arc and mercury vapor lamps and theater dimmers.

On central stations where current is furnished over a large area there is on some of the circuits, especially the long ones, a considerable "drop," or loss of potential. In order to keep the voltage at the point of supply on these circuits at the proper value, the voltage at the station must be raised. This in turn causes the voltage on those circuits near the dynamo to become excessive. Equalizers, which are large resistance boxes generally constructed of iron wire or strips and capable of carrying a heavy current, are connected in the circuits and adjusted at such resistances as to make the voltage at the various points of supply uniform. They are generally too heavy to mount on the board, but should be raised on non-combustible, non-absorptive insulating supports and should be separated from all combustible material.

Starting boxes and speed controllers are resistance boxes connected in a motor circuit and so arranged that the amount of resistance can be varied. The resistance coils are mounted in an iron case with a slate or marble front on which are placed the terminals. Dynamo field rheostats are generally mounted on the back of the marble switchboard, a small hand wheel being provided so that the rheostat can be operated from the front of the board. If the switch board is of wood in skeleton form, or if the rheostat is placed on a wall or other support of combustible material, it should be mounted on a solid piece of slate or marble. Separate screws should be used for attaching the rheostat to the slate or marble and the slate or marble to the wall for, if the same screws were used for this purpose they would be liable to ground the frame of the rheostat or might conduct heat to the material to which the rheostat is fastened. The method of fastening is shown in Figure 34 and this applies also to other forms of rheostats.

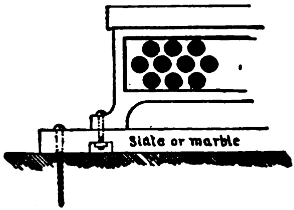


Figure 34

b. Where protective resistances are necessary in connection with automatic rheostats, incandescent lamps may be used, provided that they do not carry or control the main current nor constitute the regulating resistance of the device.

When so used, lamps must be mounted in porcelain receptacles upon non-combustible supports, and must be so arranged that they cannot have impressed upon them a voltage greater than that for which they are rated. They must in all cases be provided with a name-plate, which shall be permanently attached beside the porcelain receptacle or receptacles and stamped with the candle-power and voltage of the lamp or lamps to be used in each receptacle.

Automatic rheostats are arranged to control a motor automatically, usually from some point remote from the apparatus itself, this action being generally obtained by the use of solenoids.

The simplified diagram Figure 35 will show the manner in which this device operates. When the switch A is closed the solenoid B immediately draws up the core, at the lower end of which is attached a contact piece. The main circuit is then closed through the motor and resistance, this resistance being gradually cut out of circuit as the core moves up and the motor comes up to speed. It is very evident that considerable current will be required in the solenoid to draw up the core and contact piece and that much less current will be needed to hold it in place after it has completed its travel. As the time of operation is short the heating effect due to the current in the solenoid circuit will not have any serious effect, but if the current was left on for any great length of time the coil would

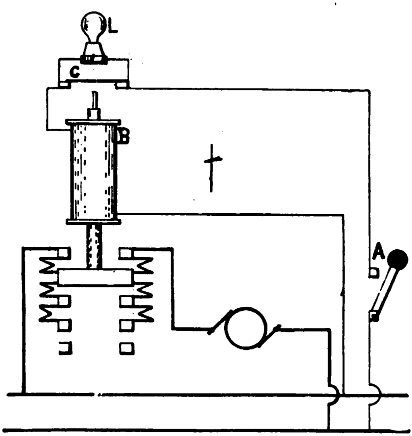


Figure 35.

be liable to burn out. To prevent this and also a waste of energy the protective resistance of the incandescent lamp L is cut into the solenoid circuit when the core has moved to its highest point by the opening of the contacts shown just below the lamp at C.

c. Wherever insulated wire is used for connection between resistances and the contact plate of a rheostat, the insulation must be "slow burning." For large field rheostats and similar resistances, where the contact plates are not mounted upon them, the connecting wires may be run together in groups so arranged that the maximum difference of potential between any two wires in a group shall not exceed 75 volts. Each group of wires must either be mounted on non-combustible, non-absorptive insulators giving at least one-half inch separation from surface wired over, or, where it is necessary to protect the wires from mechanical injury or moisture, be run in *approved* lined conduit or equivalent.

The resistance element of large field rheostats, starting devices and speed controllers are sometimes mounted separately from the contact plates, the segments on the contact plates being connected to their respective resistances by wires. If the resistance element is placed near the contact plate the wires may be run between the two on insulating supports. Where this cannot be done, or where the wires are liable to mechanical disturbance they may be grouped and run in *lined* conduit or in unlined conduit if encased in fibrous flexible conduit.

Slow burning insulation is demanded on all wires which connect to a rheostat. This class of insulation is much less liable to take fire from an overhead rheostat than the ordinary rubber covered wire, but while its heat resisting qualities are good its insulating qualities are rather poor so that under no circumstances should the difference of potential between any two wires in a group, whether the wires are run open or in conduit, exceed 75 volts. The added insulation of the lined conduit, or the flexible tubing or the insulating supports are necessary as it is possible to have the full difference of potential of the system existing between any one of the wires and the ground.

5. Lightning Arresters.

(For construction rules see No. 82.)

a. Must be attached to each wire of every overhead circuit connected with the station.

b. Must be located in readily accessible places away from combustible materials, and as near as practicable to the point where the wires enter the buildings.

In all cases, kinks, coils and sharp bends in the wires between the arresters and the outdoor lines must be avoided as far as possible.

c. Must be connected with a thoroughly good and permanent ground connection by metallic strips or wires having a conductivity not less than that of a No. 6 B. & S. gage copper wire, which must be run as nearly in a straight line as possible from the arresters to the ground connection.

Ground wires for lightning arresters must not be attached to gas pipes within the buildings nor be run inside of iron pipes.

d. All choke coils or other attachments, inherent to the lightning protection equipment, shall have an insulation from the ground or other conductors equal at least to the insulation demanded at other points of the circuit in the station.

A lightning discharge is simply a discharge of electricity at very high potential. While the insulation of the ordinary wire serves very well for the voltages for which it is designed it offers very little resistance to a current of such high potential, and, providing the discharge can reach the ground by jumping through the insulation, it will generally take that course unless some easier path is offered to it. A lightning arrester in its simplest form consists of two metal plates separated by a small air space as shown in Figure 36. One of the plates is connected to the line and the other to the ground, a set being provided for each line wire to be protected.

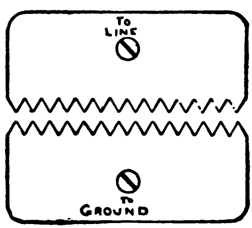


Figure 36.

The air space between the metal plates offers a much lower resistance to the passage of this high potential than do the magnets of a dynamo, for instance, or highly insulated parts of the line. The current, therefore, jumps the air space and passes to ground. When the current jumps this air space it produces an arc similar to that of an arc lamp, and after the lightning discharge is over the dynamo current is very likely to maintain this arc and thus cause a short circuit from one lightning arrester through the ground to the other. Different methods of preventing this by interrupting the arc have been devised.

Figure 37 shows the T. H. lightning arrester, in which the arc is extinguished by a magnetic field set up by the electro-magnet. In the non-arcing lightning arrester (Figure 38) the discharge takes place across the air gaps between the cylinders.

A choke coil is simply a coil of wire, the size of wire and the number of turns depending upon the normal current and voltage of the system on which it is used. On 500 volt street railway circuits the choke coil sometimes consists of a spiral of five or six turns of heavy copper rod, while on high potential, alternating current circuits a greater number of turns and smaller wire is used. As every coil of wire has a certain amount of inductance, or, in other words, tends to hold back any change in the E. M. F., the placing of a coil in the circuit between the lightning arrester and the apparatus on which the current is used affords a protection to the apparatus and forces the lightning discharge to pass to the ground through the lightning arrester.

As the lightning arrester and choke coil are subjected to extremely high potentials they should be carefully insulated and properly located.

6. Care and Attendance.

a. A competent man must be kept on duty where generators are operating.

b. Oily waste must be kept in *approved* waste cans and removed daily.

7. Testing of Insulation Resistance.

a. All circuits except such as are permanently grounded in accordance with No. 15 must be provided with reliable ground detectors. Detectors which indicate continuously and give an instant and permanent indication of a ground are preferable. Ground wires from detectors must not be attached to gas pipes within the building.

b. Where continuously indicating detectors are not feasible the circuits should be tested at least once per day, and preferably oftener.

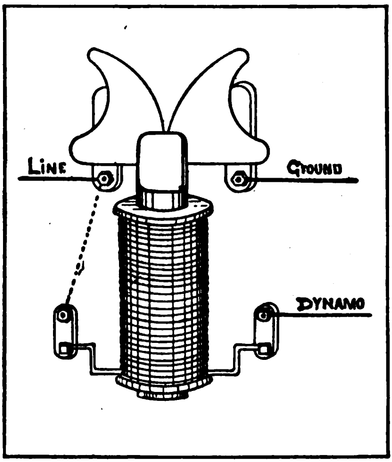


Figure 37.

The exceptions to this rule are 3-wire direct current systems where the neutral is grounded and 2 and 3 wire alternating current secondaries where the neutral or one side is grounded.

In every installation of electric wiring there is a certain "leak" of current. This leak is partly between the wires and the ground and between the wires themselves. The amount of leak varies, but is always dependent on the insulation resistance. Where a small amount of wire is well installed the leak should be very small, but in the case of large installations

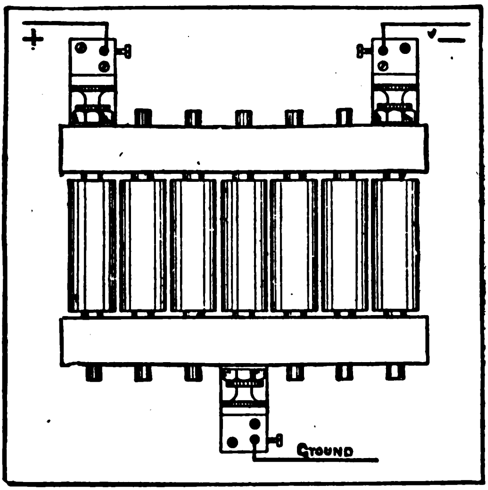


Figure 38.

or where the wiring has been poorly done the flow of current to ground or between the wires of opposite polarity may become quite large. Wires lying on pipes or on damp woodwork, crossed wires or live parts of apparatus mounted on wooden blocks, all tend to cut down the insulation resistance and increase the leak. The effects of poor insulation are:

First, it represents a useless loss of current, and, second, and more important, it means a possible cause of fire.

The simplest way to determine the insulation resistance of a circuit is by means of a voltmeter. In Figure 39 if a voltmeter of known resistance is connected between one side of the circuit and the ground and there is a ground on the other side of the circuit, say at X, current will flow from the positive wire through the voltmeter, then through the ground at X to the negative side of the circuit. The voltmeter needle will indicate a certain reading which we will call V^1. If the voltmeter is now connected directly across the circuit we get the circuit voltage, which we will call V. The two readings, V^1, and V, are to each other as the resistance of the voltmeter is to the combined resistance of the voltmeter and the ground at X; or, calling the resistance of the voltmeter R and the resistance of the ground at X r, we get

$$\frac{V^1}{V} = \frac{R}{R+r}, \text{ or } r = R\,\frac{V - V^1}{V^1}$$

As an example: On a certain system the voltage across the mains is 110, while with the voltmeter connected as shown in

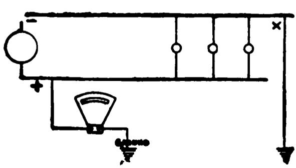


Figure 39.

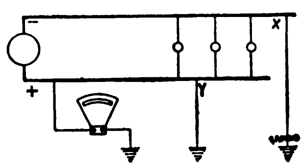


Figure 40.

Figure 39 we obtain a reading of 38. The resistance of the voltmeter is 10,500 ohms. Supplying the numbers in the formula, $r = 10{,}500 \times \frac{110-30}{30} = 28{,}000$ ohms as the resistance to ground the negative side of the system. If the voltmeter is connected to ground from the other side, or — main, the resistance to ground of the + side can be obtained.

If both sides of the system are grounded as at x and y, Figure 40, the voltmeter will be robbed of part of the current which would pass through it if Y were not in parallel with it. It will therefore not indicate correctly under such circumstances. If Y for instance were a very good ground the voltmeter would give no indication whatever of the ground at x.

If, however, tests are frequently made and defects cleared up at once when noticed it will seldom happen that two grounds occur on the system at the same time. An engineer or dynamo tender will soon learn what the insulation resistance of the plant in his charge should be and be governed accordingly.

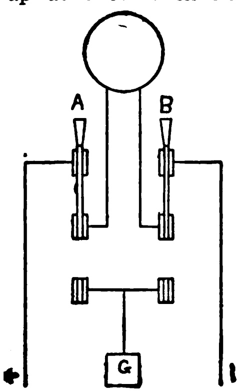


Figure 41.

A diagram of a direct current ground detector switch is shown in Figure 41. By throwing switch A down the — bus bar is connected to the ground through the voltmeter and by throwing switch B the + bar is connected to ground, through the voltmeter. The ground wire should be run to a water or steam pipe (never to a gas pipe) or to some grounded part of the building. If no good ground is obtainable one may be made as described under 15 g.

8. Motors.

a. Must, when operating at a potential in excess of 550 volts, have no exposed live metal parts and have their base frames permanently and effectively grounded.

Motors operating at a potential of 550 volts or less must be thoroughly insulated from the ground wherever feasible. Wooden base frames used for this purpose, and wooden floors, which are depended upon for insulation where, for any reason, it is necessary to omit the base frames, must be kept filled to prevent absorption of moisture, and must be kept clean and dry. Where frame insulation is impracticable, the Inspection Department having jurisdiction may, in writing, permit its omission in which case the frame must be permanently and effectively grounded.

If desired, high-potential machines may be surrounded with an insulated platform made of wood, mounted on insulating supports, and so arranged that a man must stand upon it in order to touch any part of the machine.

Where motors with grounded frames are operated on systems where one side is either purposely or accidentally grounded there exists a certain difference of potential between the windings and the motor frame, this difference of potential depending on the part of the circuit considered. At some places in the winding it will be the full difference of potential at which the motor is operating and at other points practically nothing. Should the conductors accidentally come in contact or "ground" on the motor frame a short circuit would result, as the circuit would then be completed through the motor frame and ground. To obviate this the motor frame should be insulated from the ground. This may be done either by setting the motor on a wood floor or by the use of a base frame, as with generators. A base frame should always be used where possible, for when a motor is set directly on the floor it is often impossible to keep the space under it clean, and there is always a liability of the floor being damp or of nails in the floor passing through the woodwork into some grounded part of the building or metal piping. A properly constructed base frame will allow of easy cleaning of the space under the motor,

In the case of elevator or other motors where the shunt field is suddenly broken, a momentarily high voltage is induced in the field windings. If the frame of the motor is grounded this high voltage has a strong tendency to jump through the insulation of the wires to the metal work of the motor, thus grounding the circuit.

b. Motors operating at a potential of 550 volts or less must be wired with the same precautions as required by rules in Class "C" for wires carrying a current of the same volume.

Motors operating at a potential between 550 and 3,500 volts must be wired with approved multiple conductor, metal sheathed cable in approved unlined metal conduit firmly secured in place. The metal sheath must be permanently and effectively grounded, and the construction and installation of the conduit must conform to rules for interior conduits (See No. 28), except that at outlets approved outlet bushings shall be used.

The motor leads or branch circuits must be designed to carry a current at least 25 per cent greater than that for which the motor is rated. Where the wires under this rule would be overfused in order to provide for the starting current, as in the case of many of the alternating current motors, the wires must be of such size as to be properly protected by these larger fuses.

The current used in determining the size of varying speed alternating current motor leads or branch circuits must be the percentage of the 30-minute current rating of the motor as given for the several classification of service in the following table:—

Classification of Services.	Percentage of current rating of motor.
Operating valves, raising or lowering rolls, tool heads, etc.	200
Hoists, rolls, ore and coal-handling machines	180
Freight elevators, shop cranes	160
Passenger elevators	140
Rolling tables, pumps	120

Varying speed motors are motors in which the speed varies automatically with the load, decreasing when the load increases, and vice versa. It does not mean motors in which the speed is varied by the use of different windings or grouping of windings, or motors in which the speed is varied by external means, and in which, after adjusting to a certain speed, the speed remains practically constant.

The insulation of the several conductors for high potential motors, where leaving the metal sheath at outlets, must be thoroughly protected from moisture and mechanical injury. This may be accomplished by means of a pot head or some equivalent method. The conduit must be substantially bonded to the metal casings of all fittings and apparatus connected to the inside high tension circuit.

Where outside wires direcly enter the motor room the Inspection Department having jurisdiction may permit the wires for high potential motors to be installed according to the general rules for high potential systems.

Good values to use for calculating the size of wire for branch conductors are given below. The question of loss of voltage is not taken into consideration here.

110 volts ....9.3 amperes per horsepower
220 volts ....4.6 amperes per horsepower
500 volts ....2 amperes per horsepower

For mains supplying many motors it is not necessary to provide the twenty-five per cent. overload capacity, because it is not likely that all motors will start at the same time. If, however, any one motor has more than half the capacity of the whole installation, it is advisable to provide the overload capacity. For instance, if two motors, each of 50 amperes capacity, are fed over a line of 100 amperes capacity and one is started while the other is working at full load, they will overload that line twelve and one-half per cent.

For mains supplying many small motors the size should be chosen for the total load connected, using the following values:

110 volts ....7.5 amperes per horsepower
220 volts ....3.75 amperes per horsepower
500 volts ....1.65 amperes per horsepower

Where there are a number of 110-volt motors installed on the Edison 3-wire system, providing the load is evenly balanced between the two sides, the mains may be figured as though the motors were operating at 220 volts. The reason for this will be easily seen when it is remembered that two 110-volt motors operating in series on 220 volts (as they do on the Edison 3-wire system) take only one-half the current they would if operated on a straight 2-wire 110-volt system.

c. Each motor and resistance box must be protected by a cut-out and controlled by a switch (see No. 19*a*), said switch plainly indicating whether "on" or "off" (except as provided for electric cranes, see No. 43*c*). Small motors may be grouped under the protection of a single set of fuses, provided the rated capacity of the fuses does not exceed 6 amperes. With motors of one-fourth horse power or less, on circuits where the voltage does not exceed 300, single pole switches may be used as allowed in No. 24 *c*. The switch and rheostat must be located within sight of the motor, except in cases where special permission to locate them elsewhere is given, in writing, by the Inspection Department having jurisdiction.

Where the circuit-breaking device on the motor-starting rheostat disconnects all wires of the circuit, the switch called for in this section may be omitted.

Overload-release devices on motor-starting rheostats will not be considered to take the place of the cut-out required by this section if they are inoperative during the starting of the motor.

An automatic circuit-breaker disconnecting all wires of the circuit may, however, serve as both switch and cut-out.

Every motor and starting box must be protected by a cut-out and controlled by a switch except in the case of groups of motors used on electric cranes where only one main switch is required and switches need not be placed on the separate motors. The switch and cutout must be so located that current must first pass through them before passing through the starting box or the motor. For the larger size motors a cutout must be provided for each motor, but the smaller motors, such as those of nominal 1/6th and 1/8th horse-power, may be grouped on one circuit provided the rated capacity of the fuses protecting this circuit do not exceed 6 amperes.

Small motors of the horse-power mentioned vary greatly in the current required to operate them and the horse-power ratings are generally of no value in determining the number to be allowed on a circuit. The particular conditions existing in each case must be taken into consideration and where a number of motors are to be switched on at one time the starting currents must be provided for. With alternating current motors of small horse-power ratings heavy starting currents are frequently required and motors of 1/8th horse-power rating will often blow six ampere fuses. Obviously motors of this kind must each be provided with separate circuits.

Every motor, whether large or small, must be controlled by a switch which will indicate whether the current is on or off. A motor may from overload or other causes fail to start and if a snap switch is used which does not indicate whether the current is on or off it would be easily possible to leave the motor with the current turned on.

As a general rule fused knife switches are used for the larger motors, while with the smaller motors cut-out blocks and indicating snap switches are often used. If the motor is of 1/4th horse-power or less, and operated on a circuit where the voltage does not exceed 300, a single-pole switch may be used. For all motors over 1/4th horse-power, and for all motors operated on voltages over 300, except in the case of street railway circuits, double-pole switches must be used. The reason for locating the switch and starting box within sight of the motor is that, should any trouble occur when the motor is being started, such as short circuit or overload, it will be immediately noticed and the current shut off. It is also possible that where the motor and switch are not within sight of each other some person might be working on the motor at the time it was turned on. Figure 42 shows a complete direct current motor installation as usually arranged.

If the conditions are such that it is necessary to locate the motor out of sight of the switch and starting box, the motor

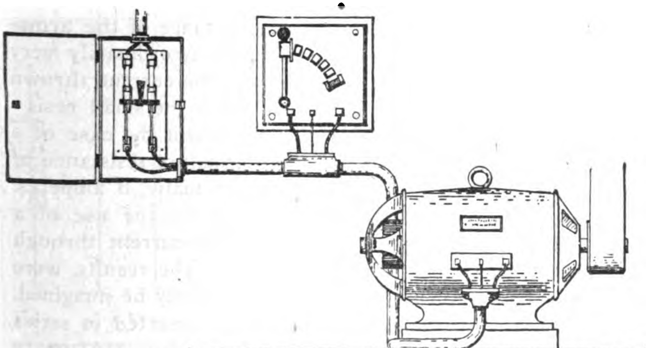


Figure 42.

should be located in a safe place away from combustible material. It may also be advisable to provide some means for determining at the point of control whether or not the motor is starting. A switch arranged at the motor to cut off the current while any one is working on it will also avoid possible accidents from that source. A special permit should be obtained from the inspection department having jurisdiction in order that the exact conditions may be noted.

d. Rheostats must be so installed as to comply with *all* the requirements of No. 4. Auto starters must comply with requirements of No. 4 *c.*

Auto starters, unless equipped with tight casings enclosing all current-carrying parts, in all wet, dusty or linty places, must be enclosed in dust-tight, fireproof cabinets. Where there is any liability of short circuits across their exposed live parts being caused by accidental contacts, a railing must be erected around them.

A starting box is a device for limiting the surrent strength during the starting of the motor by inserting a resistance in series with the armature. The ohmic resistance of the armature of a shunt or compound wound motor is ordinarily very small. When such a motor is at rest and the current thrown directly on, the full voltage is thrown across the small resisance of the armature. Consider for a moment the case of a 1 horsepower 110 volt motor having an armature resistance of say 2 ohms, and taking, when running normally, 8 amperes. Suppose the current were thrown on without the use of a starting box. According to Ohm's law the current through the armature would be 110/2=55 amperes. The results, were 55 amperes sent through the armature, can easily be imagined. Now, suppose a resistance of 8 ohms were inserted in series with the armature when starting. In this case 110/10=11 amperes only would have to pass through the armature, and this the armature can easily stand. As the motor begins to revolve a counter electro-motive force is generated which opposes the inrush of current. This counter electro-motive force increases until the motor reaches full speed and takes its normal current.

In the example given above at the first step of the starting box there will be a current of 11 amperes flowing through a resistance of 8 ohms and the power consumed will be equal to I^2R, or 968 watts, which are lost in heat produced in the resistance wire. As this amounts to more than one horsepower thrown off in heat the advisability of mounting the rheostat away from combustible material and of properly ventilating it can readily be seen.

Figure 43 shows an illustration of an *automatic* starting box, and a diagram of the connections to a motor circuit. It will be seen that the resistance coils are in series with the armature circuit. As the arm A is moved to the right, resist-

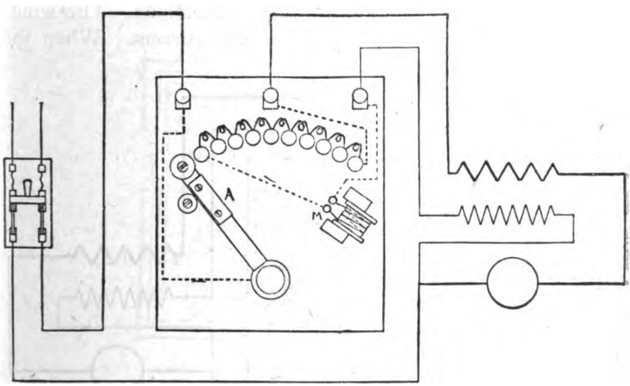


Figure 43.

ance is gradually cut out of the armature circuit until the arm reaches the last point, where it is automatically held in position by means of the small magnet M, which is connected in series with the field circuit. By tracing out the circuits it will be found that the field connection is made on the first point of the rheostat, so that when the arm A is in the "off" position there is no current passing through the field coils. It will also be noticed that the last contact upon which the arm rests when "off" is dead.

If the supply current for any reason fails, current will cease to flow around the coils of the magnet M and it will become demagnetized, thus allowing the arm A to fly back to the "off" position. This prevents the main current being momentarily shut off and then thrown on when all the resistance is out of the armature circuit. This device is known as "no-voltage" release.

Another device known as the "overload" release is shown in Figure 44, with a diagram of the connections. The winding of the magnet M^1 carries the main current. When the

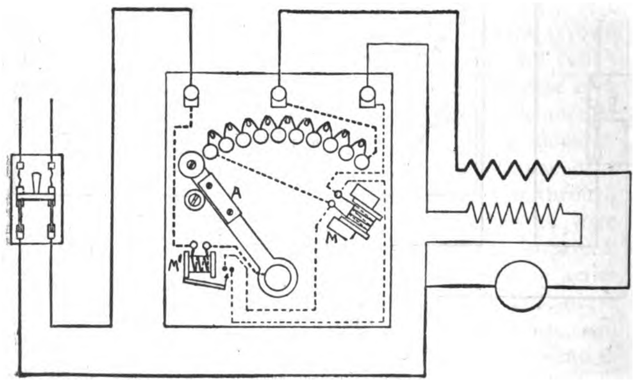


Figure 44.

current exceeds a certain amount (which can be regulated by an adjusting screw the armature below the magnet will be tracted, thus short circuiting the coil M and allowing the n to fly back and shut off the current to the motor. This vice cannot be considered to take the place of the regular ut-outs, as it is not operative during the starting of the motor. It can only operate after the arm A is held in position by the magnet M.

Starting boxes are made in different designs to meet the requirements of the various classes of work on which they

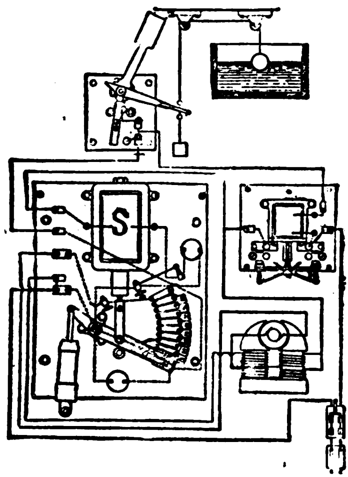


Figure 45.

are used. Figure 45 shows a large automatic starting box where the resistance is cut out by the action of the solenoid S, which draws up the movable arm. When solenoids are used for this purpose it is often advisable to arrange the connections so that when the movable arm has been raised to the highest and last point a resistance will be inserted in series with the solenoid to cut down the current and reduce the heating in the coil, as less current is required to hold the arm in place than to move it over the contacts. Incandescent lamps are often used for this purpose and must be installed as in 4, Class A.

A speed controller differs from a starting box mainly in the size of wire used as resistance. The resistance coils of a starting box are wound with comparatively small-wire and connected in circuit for a short time only, generally from ten

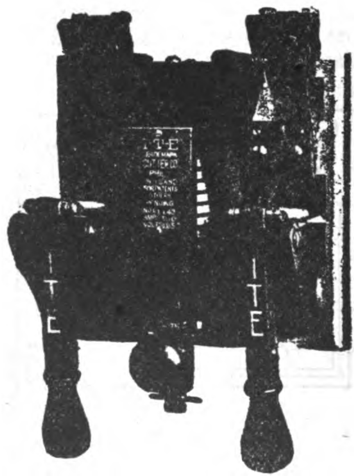


Figure 46.

to twenty seconds, while in a speed controller the wire must be of sufficient size to carry the current as long as the motor is running. Another difference between the starting box and speed controller is the automatic coil (Fig. 43) M, which in the speed controller is arranged to hold the arm A in any position in which it may be placed. This is accomplished in some types of speed controllers by a lever attached to an armature, which is attracted by the magnet M, the other end of the lever fitting into a series of indentations on lower part of movable arm.

While the underwriters' rules do not require a speed controller to be automatic, still it is good practice to make them so, as the same principles apply to the starting of a motor with a speed controller as with a starting box.

Figure 46 shows a circuit breaker which is operative during the starting of the motor, and can be used to take the place of the switch required. Circuit breakers should be frequently operated to assure that they are in working condition. This is especially necessary in wet or damp places where the mechanism is likely to become corroded and under such conditions it is sometimes advisable to use the circuit breaker for the usual operation of the apparatus in place of the switch. Overload devices on starting rheostats are also subject to corrosion in damp places and they should be frequently operated.

As the arm of a starting box or speed controller is moved from one contact to another, more or less sparking results, and, as has already been stated, considerable heat is developed in the coils. A rheostat should never be located in a room where either inflammable gases or dust exist. If a starting box is to be located in a room where considerable dirt is apt to gather, or if the room is unusually damp, the starting box should be mounted in a dust-tight fireproof box, which should be kept closed at all times, except when starting the motor. If the enclosing box is rather large, sufficient ventilation of the coils will be obtained while the motor is being started and the door open. A speed controller should never be mounted in an enclosure unless the same is arranged to give a thorough ventilation to the outside air, as heat is constantly being generated in the coils of the rheostat, and this heat must be dissipated. A speed controller should never be located where dust or lint is apt to gather on it. If it is necessary to use one on a motor located in such a place, it should be mounted outside the room.

In metal working establishments or in any place where there is a liability of the contacts on the switches or the start-

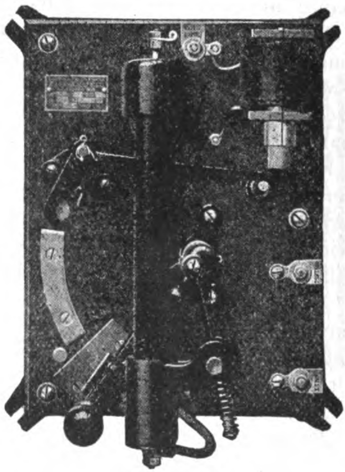


Figure 47.

ing boxes being short-circuited, they should be enclosed or suitably protected.

Rheostats used in wet or damp places are more or less liable to corrosion of both the resistance elements and the sliding contact surfaces. A rheostat which has proven itself especially applicable in such places is shown in Figure 47. This rheostat is manufactured by the Allen-Bradley Co. and consists of a number of prepared graphite discs piled in a column and placed under compression by the movement of the lever arm of the starter. An imperfect contact between the discs when under slight compression increases the resistance at starting. As the discs are compressed the contact between adjacent discs become better and the resistance is gradually decreased. These

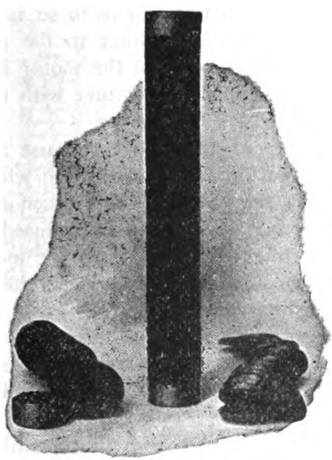


Figure 48.

starters are not affected by moisture or acid fumes. Figure 48 shows one of the resistance elements of this type starter.

With the ordinary type of rheostat having wire wound resistance tubes and sliding contacts if used in wet or damp places it is often advisable to place them in waterproof enclosures with an incandescent lamp arranged for constant burning. The heat of the lamp will keep the rheostat dry and greatly lessen the corrosion and liability of trouble.

Auto starters answer the same purpose with alternating current motors that starting boxes do with direct current motors. The method whereby this is accomplished is, however, somewhat different, the ohmic resistance inserted in the armature circuit in the case of direct current motors being replaced by an auto transformer.

An induction motor when at rest is, in so far as its starting current is concerned, very similar to the direct current motor. When current is turned on the motor is at rest and the whole device is simply a transformer with the secondary short circuited.

There are a number of auto starters in use at the present time which consist of a double throw switch with five switch blades which connect the motor to taps taken from an auto transformer for starting. This gives a reduced voltage and keeps down the starting current. When the motor is up to speed the switch is thrown over and connects the motor direct to the line with full line voltage.

This type of auto starter is often misused and where left to the care of an ordinary workman it is more likely to be abused than rightly used. It is open to the following objections:

The operator may not use the starting position at all with the result that the main line is greatly overfused to allow the enormous starting current.

He may not allow time enough on the starting position for the motor to come up to proper speed.

He may start the motor a little, open the circuit for an instant, close again, as many do thinking they are saving the motor.

He may start on the running position and leave the motor running on this position.

He may reverse the proper order and start on the running position and then move the switch to the starting position.

To obviate these difficulties the rules now demand that auto starters be designed so that they cannot be started except on the starting position and cannot be placed on the running position until they have passed through the starting position. See construction rules No. 79.

A starter designed to comply with these rules and to pro-

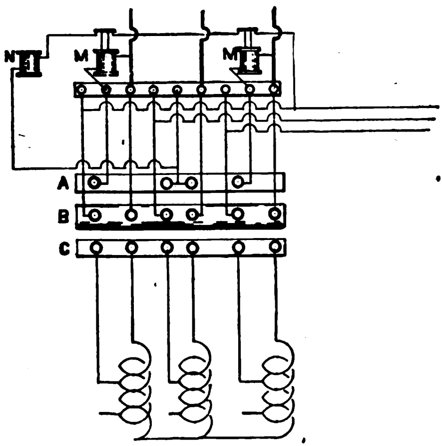


Figure 49.

vide for both overload and cessation of current is shown in Figure 49.

The two rows of contact points A and C are stationary the contact piece B being operated by a starting lever. The device is so constructed that contact must be made on the starting position, before it can be thrown on the running position. When connection is established between the contacts on B and C the motor circuit is placed in connection with the taps taken off the auto transformer and the motor starts on the reduced voltage and protected only by the fuses in the main line which must be of sufficient capacity to allow for the starting current. When the motor has come up to speed the contacts B are moved to the upper position where the motor is connected directly to the line through the two overload coils M M. The starting arm is held in position by means of the no voltage coil N. If the current fails, or if, on account of overload, the

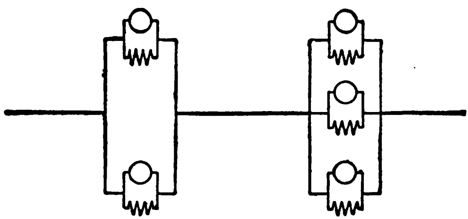


Figure 50.

no voltage coil circuit through N is broken the arm returns at the off position cutting the motor dead.

There is very little heat developed in the coils of an auto starter and they may, if of approved type, be mounted directly on wood work with no added protection.

e. Must not be run in series-multiple or multiple-series, except on constant-potential systems, and then only by special permission of the Inspection Department having jurisdiction.

Figure 50 shows a series-multiple, and Figure 51 a multiple-series system of wiring.

f. Must be covered with a waterproof cover when not in use, and, if deemed necessary by the Inspection Department having jurisdiction, must be enclosed in an *approved* case.

Such enclosures must be readily accessible, dust proof and sufficiently ventilated to prevent an excessive rise of temperature. Where practicable the sides should be made largely of glass, so that the motor may be always plainly visible.

The use of enclosed type motor is recommended in dusty places, being preferable to wooden boxing.

Under certain conditions it is found necessary to enclose motors in dust-tight enclosures. The practice of building a

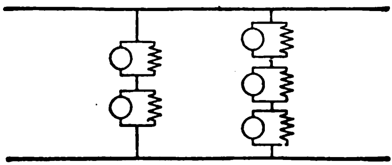


Figure 51.

small box which fits entirely around the motor, enclosing the pulley and provided with slots through which the belt passes, is very unsatisfactory. While this construction prevents considerable dust from settling on and around the motor, still a great deal will be carried in by the belt. If the box is so made that it fits tightly around the shaft between the pulley and the motor frame and is otherwise well constructed, most of the dust and dirt can be kept out. As the efficient working of the motor requires that it be kept as cool as possible, the box should afford sufficient ventilation. This may be obtained by making the box somewhat larger than the motor, thus allowing the heat to radiate from the sides, or the box should be ventilated to the outside air.

A number of motors are so constructed that, by means of hand plates, they can be entirely enclosed. When they are so enclosed their efficiency and capacities are somewhat reduced, but cases are sometimes found where the conditions require motors of this kind to be used.

In places where there is considerable dust flying about in the air, and where the dust is not readily combustible, a fine gauze can be used to close the hand holes. This gauze will allow ventilation, but will prevent the dirt from gathering inside the motor. The alternating induction motors, which are operated without brushes or collector rings, can be used in almost any location, as there is no sparking.

In large woodworking establishments there is generally compressed air available and arrangements should be provided by which the motors may be blown out regularly. Hand bellows are used for this purpose but the pressure is not sufficient for good work.

g. Must, when combined with ceiling fans, be hung from insulated hooks, or else there must be an insulator interposed between the motor and its support.

Ceiling fans are generally provided with an insulating knob on which the fan hangs. If this is not provided, a simple knob break can be used, or the fan can be suspended from a hook screwed into a hardwood block, provided the hook does not pass through the block into the plaster, the block being separately supported from the ceiling.

h. Must each be provided with a name-plate, giving the maker's name, the capacity in volts and amperes, and the normal speed in revolutions per minute.

All varying (or variable) speed alternating current motors except those used for railway service must be marked with the maximum current which they can safely carry for 30 minutes, starting cold.

i. Terminal blocks when used on motors must be made of *approved* non-combustible, non-absorptive, insulating material such as slate, marble or porcelain.

j. Adjustable speed motors, unless of special and appropriate design, if controlled by means of field regulation, must be so arranged and connected that they cannot be started under weakened field.

The speed of a motor may be changed either by inserting resistance in series with the armature, thereby cutting down the voltage at the armature terminals; or by decreasing the field current through the addition of resistance in series with the shunt field winding. By this latter method the lines of force passing through the armature gap are considerably decreased and the armature must therefore revolve at a greater speed to develop the proper counter electro-motive force. When a motor is started under a weakened field, the starting torque being reduced, the armature is slow in coming up to

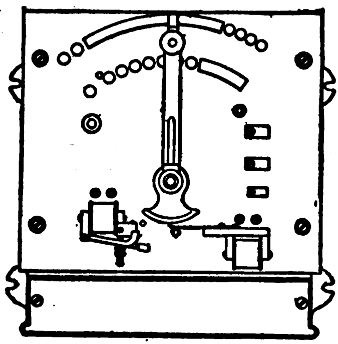


Figure 52.

speed. This prevents the rapid rise of counter E. M. F. which takes place in the ordinary motor and consequently the heavy rush of current through the armature is more likely to continue and burn out the armature.

Unless motors are so designed that they do not require this excessive current when starting under a weakened field, the field rheostat, if separate from the starting rheostat, must be provided with a no-voltage release, such as is described in Figure 43. When the field rheostat is combined with the starting rheostat the apparatus should be so constructed that the motor cannot be started under a weakened field. Figure 52 shows a starting rheostat of this kind, the last four contacts at the right being connected to the shunt field resistance. Moving the rheostat arm to the right cuts this resistance in series with the shunt field.

9. Railway Power Plants.

a. Each feed wire before it leaves the power plant must be protected by an *approved* automatic circuit-breaker or other device, which will immediately cut off the current in case of an accidental ground. This device must be mounted on a fire-proof base and in full view and reach of the attendant.

10. Storage or Primary Batteries.

a. When current for light or power is taken from primary or secondary batteries, the same general regulations must be observed as apply to similar apparatus fed from generators developing the same difference of potential.

b. Storage battery rooms must be thoroughly ventilated.

c. Special attention is directed to the rules for wiring in rooms where acid fumes exist (see No. 26 *i* and *j*).

d. All secondary batteries must be mounted on non-absorptive, non-combustible insulators, such as glass or thoroughly vitrified and glazed porcelain.

e. The use of any metal liable to corrosion must be avoided in cell connections of secondary batteries.

Rubber-covered wire run on glass knobs should be used for wiring storage battery rooms. The knobs should be of such size as to keep the wire at least one inch from the surface wired over, and they should be separated 2½ inches for voltage up to 300 and 4 inches for voltage over 300. Waterproof sockets hung from stranded rubber covered wire and properly supported independently of the joints should be used; these lights to be controlled by a switch placed outside of battery room. All joints after being properly soldered and taped with both rubber and friction tape should be painted with some good insulating compound. This tends to keep all acid fumes away from the wire.

Acid fumes are not only liable to bring about a fire hazard, but are also irritating to employes. Thorough ventilation is therefore very important. It is also important that a motor, if one is used on the ventilating fan, be kept outside the battery room as the arc produced on starting the motor is liable to cause an explosion from the accumulated gases.

11. Transformers.

(See also Nos. 14, 15, 36 and 45. For construction rules, see No. 81.)

a. In central or sub-stations the transformers must be so placed that smoke from the burning out of the coils or the boiling over of the oil (where oil filled cases are used) could do no harm.

b. In central or sub-stations casing of all transformers must be permanently and effectively grounded.

Transformers used exclusively to supply current to switchboard instruments need not be grounded, provided they are thoroughly insulated.

NOTICE.—DO NOT FAIL TO SEE WHETHER ANY RULE OR ORDINANCE OF YOUR CITY CONFLICTS WITH THESE RULES.

Class B.

OUTSIDE WORK.

(Light, Power and Heat. For Signaling Systems, see Class E.)

All Systems and Voltages.

12. Wires.

a. Line wires must have an *approved* weatherproof or rubber insulating covering. That portion of the service wires between the main cut-out and switch and the first support from the cut-out or switch on outside of the building must have an approved rubber insulating covering, but from the above mentioned support to the line, except when run in conduit, may have an approved weatherproof insulating covering, if kept free from awnings, swinging signs, shutters, etc.

By service wires are meant those wires which enter the building. It is customary to run the rubber-covered wire from the service switch and cut-out inside of building through the outer walls, and to leave but a few feet of wire to which the line wires can later be spliced. This is illustrated in Figure 55, which shows how wires are run from pole to building.

b. Must be so placed that moisture cannot form a cross connection bewteen them, and except when run in conduit, not less than a foot apart, and not in contact with any substance other than their insulating supports. Wooden blocks to which insulators are attached must be covered over their entire surface with at least two coats of waterproof paint.

For conduit work, wires must be placed so as to conform to rules for unlined conduit except that conduit system must be waterproof.

c. Must be at least seven feet above the highest point of flat roofs, and at least one foot above the ridge of pitched roofs over which they pass or to which they are attached and roof structures must be substantially constructed.

For conduit work exposed to the weather all joints should be leaded. Marine type boxes should be used, or in lieu of these, special waterproof boxes. The marine type box is provided with a threaded inlet into which the pipe can be screwed and is also provided with a gasketed cover. Special boxes follow this same design and are arranged to be made absolutely watertight. The ordinary conduit construction with locknuts and bushings should never be used for outside work.

It is well to avoid fastening wires perpendicular above one another, as in winter icicles may form which extend from the top to the lower wire, and the moisture on these will often cause much trouble. The rule requires that wires be 7 feet above flat roofs, and roof structures must, therefore, be made high enough to allow for "sag." In moderately long runs 2 or 3 feet will be sufficient. For long runs, see following table, taken from construction rules of Commonwealth Edison Company of Chicago:

The tension on wires should be such that the sag of a span of 125 feet will not exceed the amounts shown.

Temperature, F..	10	20	30	40	50	60	70	80	90
Sag, inches	6	8	8	10	10	12	12	14	14

This table will also be useful to consult when running wires over housetops to which they are not attached, as it shows the variation in "sag" due to different temperatures. Wires should be so run that even at the highest temperature they will still clear the buildings. Allowance should also be made for the gradual elongation of the wire to its own weight, giving way of supports or sleet that may at times weigh it down.

d. Must, where exposed to the weather, be provided with petticoat insulators of glass or porcelain; porcelain knobs or cleats and rubber hooks will not be approved. Wires on the exterior walls of buildings must be supported at least every fifteen feet, the distance between supports to be shortened if wires are liable to be disturbed.

Where not exposed to the weather, low potential wires may be supported on glass or porcelain knobs which will separate the wires at least one inch from the surface wired over, supports to be placed at least every four and one-half feet.

In Figure 53 single and double petticoat insulators are shown. It is very often convenient to fasten such insulators

Figure 53.

upside down or horizontally, but this should never be done, as they will then fill with water or dirt and their insulating qualities be destroyed.

e. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered, to insure preservation, and covered with an insulation equal to that on the conductors.

All joints must be soldered, unless made with some form of *approved* splicing device.

Figure 54 shows a splicing device used for large cables on outside lines.

f. Must, where they enter buildings, have drip loops outside, and the holes through which the conductors pass must be bushed with non-combustible, non-absorptive, insulating tubes slanting upward toward the inside.

For low-potential systems the service wires may be brought into buildings through a single iron conduit. The conduit to be equipped with an *approved* service-head. The inner end must extend to the service cut-out, and if a cabinet is required by the Code must properly enter the cabinet.

The manner of bringing in overhead services is shown in Figure 55.

Although the rule does not specify the height at which service wires must be brought out it is good practice to bring

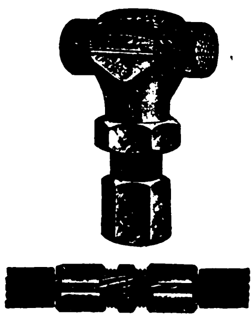


Figure 54.

them out at the level of the ceiling of the second floor. In almost all cases telephone wires are run on the lower cross arms of poles and if the service wires are brought out as suggested little trouble will be encountered from interference with these wires.

g. Electric light and power wires must not be placed on the same cross-arm with telegraph, telephone or similar wires, and when placed on the same pole with such wires the distance between the two inside pins of each cross-arm must not be less than twenty-six inches.

h. The metallic sheaths to cables must be permanently and effectively connected to "earth."

Telephone or telegraph wires are sometimes placed above power wires and it then becomes necessary for a lineman to pass through the lower wires, which are generally of a high potential, to get to the upper ones. Great care is then nec-

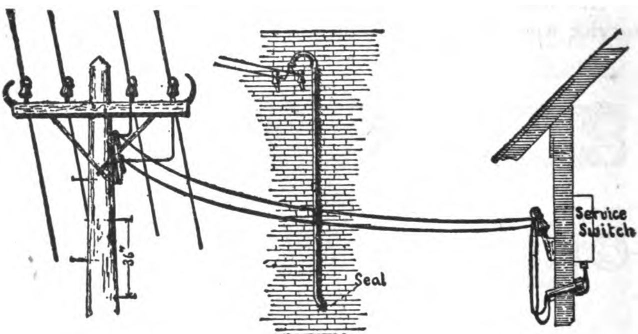


Figure 55.

cessary both in passing through the wires and in working on the upper wires. The better practice is to place the power (or lighting) wires on the upper cross arms. Being stronger, they are less liable to break and fall on the lower wires, and it is then unnecessary for the lineman working on the telephone or telegraph wires to come near the higher potential wires.

Poles should not be set more than 125 feet apart; 100 or 110 feet is good practice. For small wires poles with 6-inch tops are often used, but for heavier wires 7-inch tops are advisable. The tops of pole should be pointed, so as to shed water, and the whole pole be well painted. Steps should be placed so that the distance between any two steps on the same side is not over 36 inches; these steps should all be the same distance apart, and should not extend nearer than 8 feet to the ground. All "gains" cut into poles should be painted before cross-arms are placed in them. Such places are more likely to hold moisture and rot than exposed parts. Where-ever feed wires end or sharp angles occur, double cross-arms should be used, fastened on opposite sides of pole and bolted together.

All bolts, lag screws, etc., should be galvanized. Poles should be set at least as far into the ground as shown in the following table:

Length of poles.	Depth in ground.
35 feet	5½ feet
40 feet	6 feet
45 feet	6 feet
50 feet	6½ feet
55 feet	7 feet.
60 feet	8 feet

The holes should be large enough to admit of thorough tamping on all sides of bottom of hole. If the tamping at bottom of hole is not well done, the pole will always be shaky, no matter how much tamping may be done at the top. If the ground is soft, the pole may be set in cement, or short pieces of planking fastened to it at right angles underground. At the end of line or where sharp bends occur, strong galvanized guy cables fastened to poles six or eight feet long, buried underground should be used.

Trolley Wires.

i. Must not be smaller than No. 0 B. & S. gage copper or No. 4 B. & S. gage silicon bronze, and must readily stand the strain put upon them when in use.

j. Must have a double insulation from the ground. In wooden pole construction the pole will be considered as one insulation.

k. Must be capable of being disconnected at the power plant, or of being divided into sections, so that in case of fire on the railway route, the current may be shut off from the particular section and not interfere with the work of the firemen. This rule also applies to feeders.

l. Must be safely protected against accidental contact where crossed by other conductors.

Where guard wires are used they must be insulated from the ground and electrically disconnected in sections of not more than 300 feet in length.

Ground Return Wires.

m. For the diminution of electrolytic corrosion of underground metal work, ground return wires must be so arranged that the difference of potential between the grounded dynamo terminal and any point on the return circuit will not exceed twenty-five volts.

It is suggested that the positive pole of the dynamo be connected to the trolley line, and that whenever pipes or other underground metal work are found to be electrically positive to the rails or surrounding earth, that they be connected by conductors arranged so as to prevent as far as possible current flow from the pipes into the ground.

Where trolley wires enter buildings an arrangement such as shown in Figure 56 is often used. The car in passing

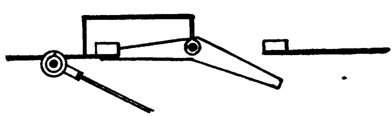


Figure 56.

forces the arm at the right upward energizing the trolley wire inside the building. When the car leaves the building the left arm is forced up and the trolley wire inside the building disconncted.

In cases where the trolley wire passes through the building arrangements may be made so that the same action is obtained through the medium of electro magnets energized as the car enters and leaves the building.

13. Constant-Potential Pole Lines, Over 5,000 Volts.

(Overhead lines of this class unless properly arranged may increase the fire loss from the following causes:

Accidental crosses between such lines and low-potential lines may allow the high-voltage current to enter buildings over a large section of adjoining country. Moreover, such high voltage lines, if carried close to buildings, hamper the work of firemen in case of fire in the building. The object of these rules is so to direct this class of construction that no increase in fire hazard will result, while at the same time care has been taken to avoid restrictions which would unreasonably impede progress in electrical development.

It is fully understood that it is impossible to frame rules which will cover all conceivable cases that may arise in construction work of such an extended and varied nature, and it is advised that the Inspection Department having jurisdiction be freely consulted as to any modification of the rules in particular cases.)

a. Every reasonable precaution must be taken in arranging routes so as to avoid exposure to contacts with other electric circuits. On existing lines, where there is a liability to contact, the route should be changed by mutual agreement between the parties in interest wherever possible.

b. Such lines should not approach other pole lines nearer than a distance equal to the height of the taller pole line, and such lines should not be on the same poles with other wires, except that signaling wires used by the company operating the high-pressure system, and which do not enter property other than that owned or occupied by such company, may be carried over the same poles.

c. Where such lines must necessarily be carried nearer to other pole lines than is specified in Section *b* above, or where they must necessarily be carried on the same poles with other wires, extra precautions to reduce the liability of a breakdown to a minimum must be taken, such as the use of wires of ample mechanical strength, widely spaced cross-arms, short spans, double or extra heavy cross-arms, extra heavy pins, insulators, and poles thoroughly supported. If carried on the same poles with other wires, the high-pressure wires must be carried at least three feet above the other wires.

d. Where such lines cross other lines, the poles of both lines must be of heavy and substantial construction.

Wherever it is feasible, end-insulator guards should be placed on the cross-arms of the upper line. If the high-pressure wires cross below the other lines, the wires of the upper line should be dead-ended at each end of the span to double-grooved, or to standard transposition insulators, and the line completed by loops.

One of the following forms of construction must then be adopted:

1. The height and length of the cross-over span may be made such that the shortest distance between the lower cross-arms of the upper line and any wire of the lower line will be greater than the length of the cross-over span, so that a wire breaking near one of the upper pins would not be long enough to reach any wire of the lower line. The high-pressure wires should preferably be above the other wires.

By reference to Fig. 57 it will be seen that the first plan of making cross-over is not very practical. In the lower left hand corner the vertical lines drawn alongside of the pole show the rate at which poles must be lengthened to comply with the rules when they are some distance from the pole to be crossed.

If a line is to be crossed in this manner, economy and also good construction require that the poles be set close to the line to be crossed as shown at the right of the figure. The poles here are about twice the length of the cross-arm apart. The wires between the two poles cannot touch the lower wires

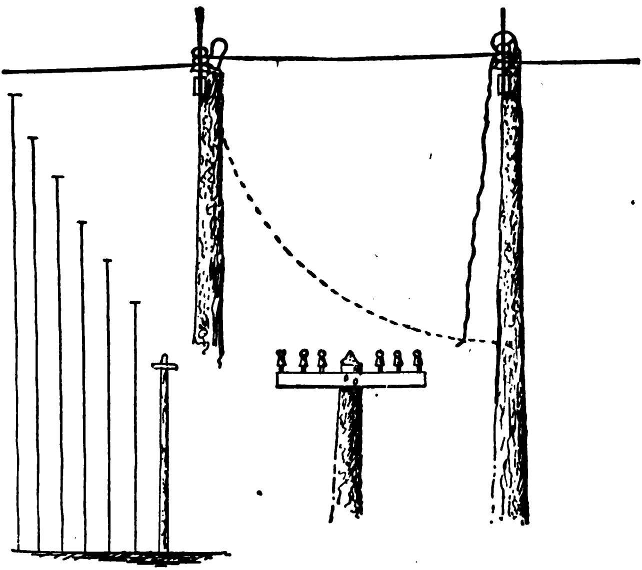


Figure 57.

and the expense of the cross-over is only the setting of one pole and its cross-arms, etc. With the poles set as close as this there remains, however, the possibility of a wire in one of the adjacent spans breaking and, if strongly whipped about by the wind, being lashed against the lower wires. Guard wires can in a measure prevent such a wire coming in contact with the lower wire, but it is conceivable that the wire in question be broken off at such a distance from the pole that it will swing over and lodge on top of the lower wires. If the cross-over poles are to be set farther apart to lessen this danger, they must be increased two feet in height for every foot they are moved to one side.

Figure 58 is a suggestion towards making crosses on a joint pole. It is simply a trough-like screen built around

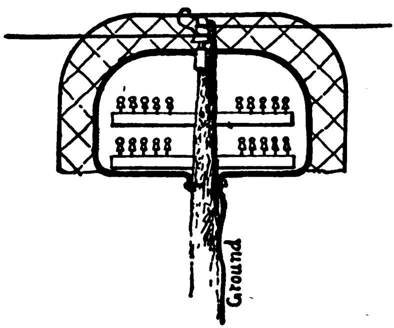


Figure 58.

the lower wires and set so that it must catch the upper wires when they break and confine them so that the wind cannot whip them out.

A cross-over made on a joint pole in some such manner as this is probably the most satisfactory. Wires are absolutely prevented from coming together, and such a pole being braced by the wires in two ways would seem to be quite safe. When wires cross at rather an acute angle the screen mentioned stretched from pole to pole under the upper wires is probably the best safeguard.

2. A joint pole may be erected at the crossing point, high-pressure wires being supported on this pole at least three feet above the other wires. Mechanical guards or supports must then be provided, so that in case of the breaking of any upper wire it will be impossible for it to come into contact with any of the lower wires.

Such liability of contact may be prevented by the use of suspension wires, similar to those employed for suspending aerial telephone cables, which will prevent the high-pressure wires from falling in case they break. The suspension wires should be supported on high potential insulators, should have ample mechanical strength, and should be carried over the high-pressure wires for one span on each side of the joint pole, or where suspension wires are not desired guard wires may be carried above and below the lower wires for one span on each side of the joint pole, and so spread that a falling high-pressure wire would be held out of contact with the lower wires.

Such guard wires should be supported on high-potential insulators or should be grounded. When grounded, they must be of such size, and so connected and earthed, that they can surely carry to ground any current which may be delivered by any of the high-pressure wires. Further, the construction must be such that the guard wires will not be destroyed by any arcing at the point of contact likely to occur under the conditions existing.

3. Whenever neither of the above methods is feasible a screen of wires should be interposed between the lines at the cross-over. This screen should be supported on high tension insulators or grounded and should be of such construction and strength as to prevent the upper wires from coming into contact with the lower ones.

If the screen is grounded each wire of the screen must be of such size and so connected and earthed that it can surely carry to ground any current which may be delivered by any of the high pressure wires. Further, the construction must be such that the wires of screen will not be destroyed by any arcing at the point of contact likely to occur under the conditions existing.

e. When it is necessary to carry such lines near buildings, they must be at such height and distance from the building as not to interfere with firemen in event of fire; therefore, if within 25 feet of a building, they must be carried at a height not less than that of the front cornice, and the height must be greater than that of the cornice, as the wires come nearer to the building, in accordance with the following table:—

Distance of wire from building. Feet.	Elevation of wire above cornice of building. Feet.
25	0
20	2
15	4
10	6
5	8
2½	9

It is evident that where the roof of the building continues nearly in line with the walls, as in mansard roofs, the height and dis-

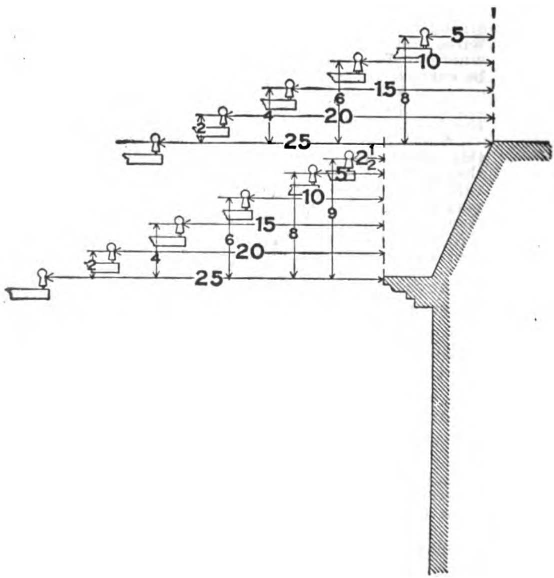


Figure 59.

tance of the line must be reckoned from some part of the roof instead of from the cornice.

A graphic illustration of the rule concerning the placing of poles near buildings is given in Figure 59. The upper group of figures and insulators shows the distance from the building and the corresponding height above high point of roof required with mansard roofs. Distance being measured from the roof. The lower groups show measurements taken from cornice line as will be proper with ordinary flat roofed buildings.

14. Transformers.

(See also Nos. 11, 15, 36 and 45. For construction rules, see No. 81.)

Where transformers are to be connected to high-voltage circuits, it is neecssary in many cases, for best protection to life and property, that the secondary system be permanently grounded, and provision should be made for it when the transformers are built.

a. Must not be placed inside of any building, excepting central stations and sub-stations (except as provided in No. 36), unless by special permission of the Inspection Department having jurisdiction.

b. Must not be attached to the outside walls of buildings, unless separated therefrom by substantial supports.

Must not be attached to frame buildings when any other location is practicable.

As a rule transformers are fastened to buildings on horizontal bars of wood. This method is as satisfactory as any if the wood itself is securely enough fastened to the wall. The wooden supports of the transformer should be fastened to the wall either by suitable expansion bolts or better still by bolts passing entirely through the wall. In fastening transformers to poorly constructed walls where permission to go through the wall cannot be obtained, some advantage can be gained by supporting the transformer supports set vertically as shown in Figure 60. It must be borne in mind that there is not only a downward strain on the supports but also an outward tipping strain. Almost any wall will stand the downward strain but in a loosely constructed wall there may not be a good hold for the bolts and a heavy transformer may tear them out as indicated. If the transformer is supported as shown the supports may be distributed over a much larger wall area and a much greater leverage obtained against tipping strain than would be possible with horizontally arranged timbers. It

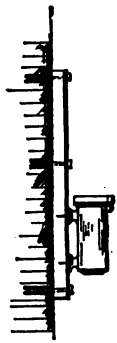


Figure 60.

is always better practice when possible to keep transformers off of buildings and mount them on poles.

The alternating current transformer consists of an iron core upon which wires of two distinct electrical circuits are wound. One of these is known as the *primary* circuit, and in it the high pressure currents coming direct from the dynamo circulate. The other is known as the *secondary* circuit, and in it the low pressure currents used inside of building circulate. These two circuits are wound generally one over the other, and are very close together. The pressure used in the primary coil is from 1,000 to 5,000 volts, while in the secondary it is reduced usually to 110 or 220.

It quite frequently happens that the insulation between the two windings breaks down and thus the high pressure is accidentally brought into buildings. Under such circumstances should any one touch any live part of the installation while touching also grounded parts of the building death would very likely result. Also, should there be a weak spot in the insulation, it is quite likely the high pressure would pierce it at that point with a possible result of a fire. Many deaths and fires have been caused in this way. If such lines are connected to ground the chances for harm are very much lessened, for the current will never take the path of high resistance through a man's body while a direct path through a low resistance wire is open to it.

It must not be supposed that "grounding" one side of an electric light system is not often followed by serious consequences, for under such circumstances a ground coming on any other part of the system will cause a short circuit at once. The grounding in these cases is to be looked upon as the lesser of two evils rather than as an advantage.

Grounding the secondary tends to increase the danger from fire by increasing the electrical strain on the wires and fittings and, further, by increasing the tendency to short circuits. In an ungrounded system there is always the insulation of both sides of the system between conductors of opposite polarity as, for instance, in the case of the wires where current must pass through two insulations before a short circuit can occur, it is also necessary for both sides of the system to become grounded before a short circuit can occur. In the grounded system the insulation on the grounded wire is useless so far as short circuits through the ground are concerned as current must pass through one insulation only to produce a short.

On the other hand the danger to life is greatly decreased by the grounding of the secondary as has already been explained, and the danger from fire is somewhat decreased by making it impossible for the high tension current to enter the building. As secondary voltages for commercial use vary from 110 to 550 volts it is evident that some limit must be placed on the secondary voltage which it shall be permissible to ground. Obviously it would be inadvisable to ground a secondary having a potential of 550 volts to ground as the danger from fire and to life would be greatly increased. The proper limiting voltage for grounding has been a subject of much discussion. The solution of the question as it effects the fire hazard is determined by the number of fires occuring on systems with grounded secondaries from short circuits on the secondary and the number of fires occurring from crosses between the primary and secondaries. The proper voltage is, of course, that voltage which will give the minimum number of fires.

The limiting voltage from the life standpoint is likewise determined. It is a matter of record that numbers of fatal accidents have occurred from contact with both 110 and 220 volt circuits, while a contact with a secondary which has become crossed with the primary nearly always results fatally. The Underwriters have set the limiting voltage at 250. (See Rule 15 b.)

With alternating currents, the chances of possible damage from grounding are less than with direct currents, because each transformer with its small group of lamps is a system by itself and not affected by grounds on other transformers. Thus a 5,000 light alternating current installation would consist of from 25 to 50 separate systems, each independent of defects on the rest, while in a continuous current installation a ground on the most remote branch circuit would, in conjunction with a ground on the opposite side of any other part of the system, form a short circuit.

The benefits of both the grounded and the ungrounded secondary system can be obtained by interposing a one to one transformer in the secondary circuit. This transformer does not alter the voltage but simply insulates the two parts

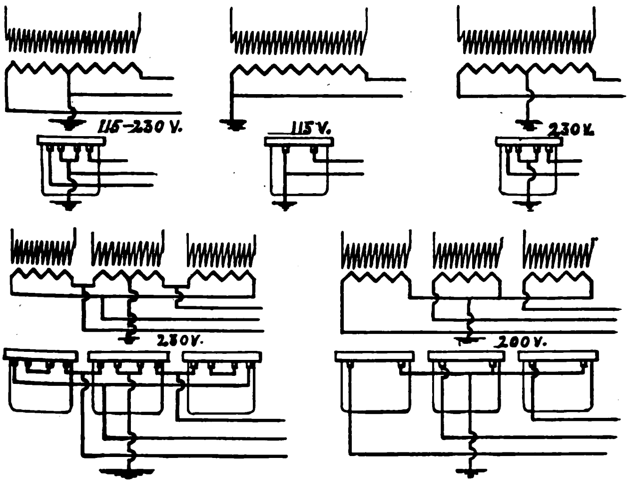


Figure 61.

of the secondary circuit. It is frequently used where the secondaries are especially liable to grounds as in packing houses and breweries.

Methods of grounding secondary wires of alternating current transformers are shown in Figure 61.

In connection with 3-wire systems, grounding of the neutral wire can do little harm, because ordinarily the neutral wire seldom carries much current, and that current is apt to vary in direction so that the electrolytic effect will be on the whole quite negligible.

In connection with 3-wire systems, however, it is of the greatest importance (as more fully explained further on) that the neutral wire remain intact, and it being thoroughly grounded at all available outside places will help to keep it so.

15. Grounding Low-Potential Circuits.

The grounding of low-potential circuits under the following regulations is only allowed when such circuits are so arranged that under normal conditions of service there will be no passage of current over the ground wire.

Direct-Current 3-Wire Systems.

a. Neutral wire may be grounded, and when grounded the following rules must be complied with:—

1. Must be permanently and effectively grounded at the Central Station. The ground connection must include all available underground water and gas pipe systems.
2. In underground systems the neutral wire must also be grounded at each distributing box through the box.
3. In overhead systems the neutral wire must be grounded every 500 feet, as provided in Sections *c* to *g*.

Inspection Departments having jurisdiction may *require* grounding if they deem it necessary.

Two-wire direct-current systems having no accessible neutral point are not to be grounded.

Alternating-Current Secondary Systems.

b. Tarnsformer secondaries of distributing systems should preferably be grounded, and when grounded, the following rules must be complied with:—

1. The grounding must be made at the neutral point or wire, whenever a neutral point or wire is accessible.
2. When no neutral point or wire is accessible, one side of the secondary circuit may be grounded, provided the maximum difference of potential be-

tween the grounded point and any other point in the circuit does not exceed 250 volts.

3. The ground connection must be at the transformers or on the individual service as provided in sections *c* to *g*, and when transformers feed systems with a neutral wire, the neutral wire must also be grounded at least every 500 feet.

Inspection Departments having jurisdiction may *require* grounding if they deem it necessary.

Ground Connections.

c. When the ground connection is inside of any building, or the ground wire is inside of, or attached to any building (except Central or Sub-stations), the ground wire must be of copper and have an approved rubber insulating covering National Electrical Code Standard, for from 0 to 600 volts.

d. The ground wire in direct-current 3-wire systems must not at Central Stations be smaller than the neutral wire and not smaller than No. 6 B. & S. gage elsewhere. The ground wire in alternating-current systems must never be less than No. 6 B. and S. gage.

On three-phase system, the ground wire must have a carrying capacity equal to that of any one of the three mains.

e. The ground wire should, except for Central Stations and transformer sub-stations, be kept outside of buildings as far as practicable, but may be directly attached to the building or pole by cleats or straps or on porcelain knobs. Staples must never be used. The wire must be carried in as nearly a straight line as practicable, avoiding kinks, coils and sharp bends, and must be protected when exposed to mechanical injury.

This protection can be secured by use of approved conduit or moulding, and as a rule the ground wire on the outside of a building should be in conduit or moulding at all places where it is within seven feet from the ground.

f. The ground connection for Central Stations, transformer sub-stations, and banks of transformers must be permanent and effective and must include all available underground piping systems including the lead sheath of underground cables.

g. For individual transformers and building services, the ground connection may be made as in Section *f*, or may be made to water piping systems running into buildings. This connection may be made by carrying the ground wire into the cellar and connecting on the street side of meters, main cocks, etc.

Where it is necessary to run the ground wire through any part of a building, unless run in approved conduit, it shall be protected by porcelain bushings through walls or partitions and shall be run in approved moulding, except that in basements it may be supported on porcelain.

In connecting a ground wire to a piping system, the wire should be sweated into a lug attached to an approved clamp, and the clamp firmly bolted to the water pipe after all rust and scale have been removed; or be soldered into a brass plug and the plug forcibly screwed into a pipe fitting, or where the pipes are cast iron, into a hole tapped into the pipe itself. For large stations, where connecting to underground pipes with bell and spigot joints, it is well to connect to several lengths, as the pipe joints may be of rather high resistance.

Where ground plates are used; a No. 16 Stubbs' gage copper plate, about three by six feet in size, with about two feet of crushed coke or charcoal, about pea size, both under and over it, would make a ground of sufficient capacity for a moderate-sized station, and would probably answer for the ordinary sub-station or bank of transformers. For a large central station, a plate with considerably more area might be necessary, depending upon the other underground connection available. The ground wire should be riveted to the plate in a number of places, and soldered for its whole length. Perhaps even better than a copper plate is a cast-iron plate with projecting forks, the idea of the fork being to distribute the connection to the ground over a fairly broad area, and to give a large surface contact. The ground wire can probably best be connected to such a cast-iron plate by soldering it into brass plugs screwed into holes tapped in the plate. In all cases, the joint between the plate and the ground wire should be thoroughly protected against corrosion by painting it with waterproof paint or some equivalent.

NOTE.—DO NOT FAIL TO SEE WHETHER ANY RULE OR ORDINANCE OF YOUR CITY CONFLICTS WITH THESE RULES.

CLASS C.

INSIDE WORK.

(Light, Power and Heat. For signaling systems, see Class E.)

ALL SYSTEMS AND VOLTAGES.

General Rules.

16. Wires.

(See also Nos. 17, 18, 20, 26, 27, 44, 47 and 48. For construction rules, see Nos. 49 to 57.)

a. Must not be of smaller size than No. 14 B. & S. gage, except as allowed for fixture work and pendant cord.

For general purposes a wire smaller than No. 14 is too easily broken, either through a sharp kink or by drawing too tight with tie wires. To avoid trouble from kinks or sharp bends, wires smaller than 14 should preferably be stranded.

b. Tie wires must have an insulation equal to that of the conductors they confine, and may be used in connection with solid knobs for the support of wires of size No. 8 B. & S. gage or over. Solid knobs or strain insulators must be used for all wires at the end of runs where conductors are terminated. Split knobs or cleats must be used for the support of conductors smaller than No. 8 B. & S. gage, except at the end of runs.

Knobs or cleats which are arranged to grip the wire, must be fastened by either screws or nails. If nails are used, they must be long enough to penetrate the woodwork not less than

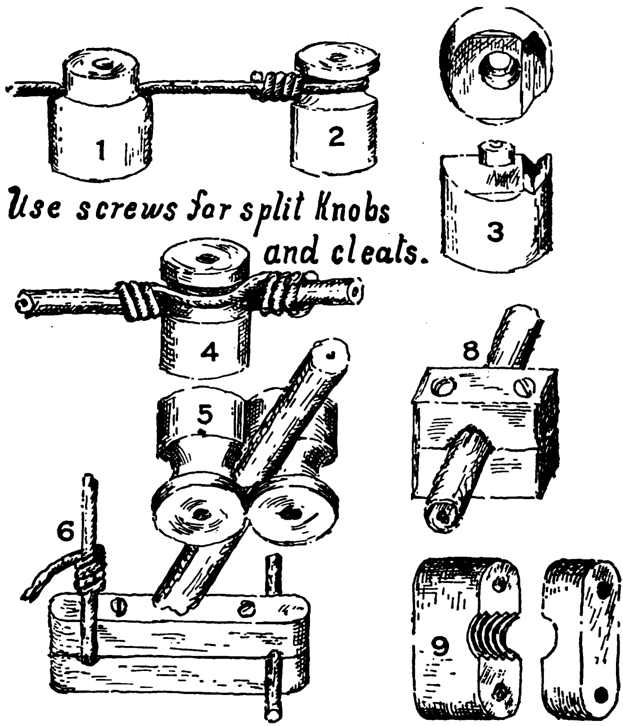


Figure 62.

one-half the length of the knob and fully the thickness of the cleat, and must be provided with washers which will prevent under reasonable usage, injury to the knobs or cleats.

It is necessary where tie wires are used that they have an insulation the same as that of the conductor they confine. The tie wire often cuts into the insulation of the line wire and if it was not insulated it would become alive. The larger bearing surface given by the insulated wire will also reduce the liability of the tie wire cutting in.

Formerly it was customary to use a solid knob and tie wire on all sizes of wire, but the present rule limits this type of knob to wires of No. 8 and larger. The main objection to the tie wire, especially with wires of small size, was the

Figure 63.

liability of the tie wire becoming loose and letting the line wire fall from the knob. This objection is overcome in the split knob where the wire is gripped directly by the porcelain knob itself. At the ends of runs the split knob must not be used but a solid knob as shown at (2), Figure 62, or a strain insulator as shown in Figure 63, may be used. Figure 62 also shows other methods of supporting wires. At (4) is shown the manner of tying large wires of No. 8 B. & S. gage and larger; (6), shows a knot tied into the wire as is usual where the end of the wire connects into cut-outs or switches. At (5) insulators are arranged to hold large wires. It is not advisable to tie large wires to insulators as the weight of the wire will soon cause it to cut through the insulation. Cleats such as are shown at (8) and (9) are preferable.

c. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered unless made with some form of *approved* splicing device, and covered with an insulation equal to that on the conductors.

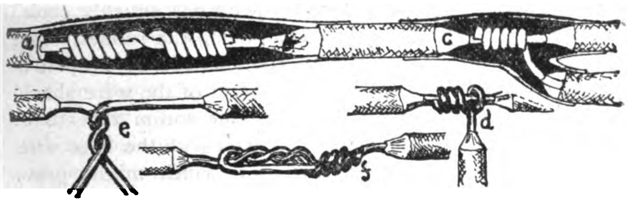
Stranded wires (except in flexible cords) must be soldered before being fastened under clamps or binding screws, and whether stranded or solid, when they have a conductivity greater than that of No. 8 B. & S. gage they must be soldered into lugs for all terminal conections, except where an *approved* solderless terminal connector is used. See Figure 54.

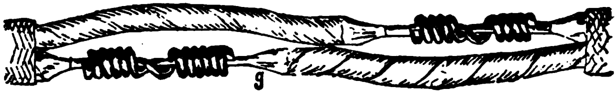
On the left at the upper part of Figure 64 is shown the well-known Western Union joint. Before joining wires they should be thoroughly cleaned by scraping with the back of a knife or sand or emery paper. The insulation should be removed, as indicated at *b;* if it is cut into as at *a,* it is very likely that the wire will be "nicked" and will be likely to break at that point. It is also more difficult to tape a joint properly if the rubber has been cut in this way than it is with the rubber cut as at *b.* After the joint has been made it is covered with soldering fluid, a formula for which is given below. In lieu of this there are soldering sticks and salts, already prepared, on the market.

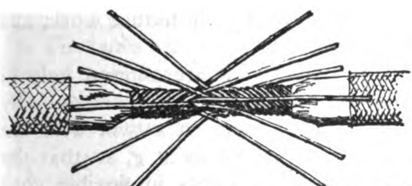
The following formula for soldering fluid is suggested:—

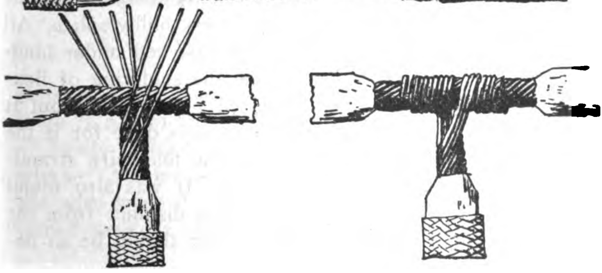
Saturated solution of zinc chloride.......	5 parts
Alcohol	4 parts
Glycerine	1 part

The joint having been thoroughly covered with one of these preparations is next heated with a gasoline or alcohol torch and a small piece of solder allowed to melt on it near the center. It is well to avoid heating too much at the ends of the joint, as it weakens the wire. After the joint is partly cooled wipe off all moisture and cover with layers of rubber tape, enough, at least, so that it is equal in thickness to the rubber insulation on the wire used, as shown at *a* and *b.* If


a
c
d
e
f


g





the rubber tape is put on before the wire has entirely cooled the remaining heat will assist in vulcanizing the rubber. This rubber tape is then covered with friction tape to keep it in place. Before taping joints the outer braid of the wire should be carefully skinned back. If any of the cotton threads of which it consists were to be left in contact with the bare wire, they would, when moist, form a leak, which might prove troublesome. If joints are exposed to the weather it will be well to paint them over with some insulating paint to keep the friction tape in place, as it will otherwise soon work loose when it becomes dry.

At *c* and *d* "tap" joints are shown. The method shown at *d* is preferable, because the wire cannot easily work loose. The method of joining shown at *e* is useful when, for instance, two wires, each of which is fastened to an insulator, are to be joined. The wires can be drawn very tight in this way. This sort of joint is very common in fixture work, and should be finished off as at *f*.

Twin wires other than flexible cord are allowed only in metal conduits, and joints in them should be made only within the junction boxes. When joints in a twin wire are unavoidable, the wires should be joined as at *g*, so that the joints are not opposite each other. Joints in flexible cord should be avoided.

In splicing stranded wires it is customary to remove some of the center strands to avoid making a very bulky splice. All stranded wires must be soldered where fastened under binding screws. The rule does not require the soldering of flexible cords. Formerly this was required by the rules but it has been found that more harm than good is done for if the soldering was not done very carefully the fine wire strands were made brittle and would break off. It was also found that the insulation was destroyed for some distance from the point of soldering. The lining of a socket should be so designed as to thoroughly protect any stray strands which may protrude from the wire under the binding post from coming in contact with the metal of the socket. If it is desired to solder the ends of the cord before fastening under binding posts this is best done by dipping the ends into molten solder taking care that the copper is cooled before it has had time to heat the rubber insulation.

Figure 65 shows lead covered wire spliced and taped. In handling lead covered wire great care must be exercised (especially with paper insulated) that it be not bruised and the lead not punctured. The lead covering is of use only as a protection against water; if it admits the least bit of moisture it is worse than useless. In cutting the lead off from the end of the cable great care should be taken that the insulation is not injured. The best practice is to cut the lead only partly through then, by slightly bending the cable, break the lead and pull it off.

The ends of lead covered wires should always be kept sealed until ready for use; in damp places the paper insulation may absorb moisture, which will ground the wire on the lead. When installed the ends should always be sealed against

Figure 65.

moisture. Lead covered wires should never be used where there is a liability of nails being driven into them.

Joints in lead covered wires are made just as in ordinary wires. Extreme care is necessary that no moisture be left on the wire when it is taped or covered up. Before the wire is joined a sleeve (Figure 65) is slipped over one of the wires.

After the joint has been made and taped, this sleeve is placed so as to cover it, and the ends hammered down to fit close against the lead on the wires. That part of the lead which must be soldered to make the joint watertight is scraped until it is perfectly bright and then coated with tallow candle grease. It can then be soldered with an iron, or melted solder can be poured on it and wiped around it, as plumbers do. If a soldering iron is used it must not be too hot and not allowed to remain in one place too long, as the lead itself melts at nearly the same temperature as the solder. An inexperienced workman may burn more holes into the lead than he closes. If a neat job is desired, that part of the lead which is to be kept free of solder is covered with lampblack and glue, or ordinary paper hanger's paste, or a mixture of flour and water boiled, so as to prevent the solder from taking on it.

A Western Union joint, as shown in Figure 65, is somewhat objectionable in lead covered wires on account of the amount of space required by the joint itself. If this form of connection is used it is generally necessary to provide a lead sleeve somewhat larger than the outside diameter of the lead covering of the wire and the end of this sleeve must then be tapered down to conform to the lead covering. To overcome this objectionable feature joints are made as shown in Figure 66, where (a) shows a copper sleeve slipped over the ends

Figure 66.

of the wire, the whole being thoroughly soldered. The wires may be either butted together or lapped as shown by the dotted lines. In place of the metal sleeve the ends of the wires may be lapped and bound together by a small copper wire as shown at (b), the whole being soldered; this, however, is not as strong a joint as that made with a sleeve. Large stranded cables are joined as shown at *a*, Figure 66 or they may be joined as shown at the lower part of Figure 64.

d. Must be separated from contact with walls, floors, timbers or partitions through which they may pass by non-combustible, non-absorptive, insulating tubes, such as glass or porcelain, except at outlets where approved flexible tubing is required.

Bushings must be long enough to bush the entire length of the hole in one continuous piece, or else the hole must first be bushed by a continuous waterproof tube. This tube may be a conductor, such as iron pipe, but in that case an insulating bushing must be pushed into each end of it, extending far enough to keep the wire absolutely out of contact with the pipe.

e. Where not enclosed in approved conduit, moulding or armored cable and where liable to come in contact with gas, water, or other metallic piping or other conducting material, must be separated therefrom by some continuous and firmly fixed non-conductor creating a permanent separation. Must not come nearer than 2 (two) inches to any other electric lighting, power or signaling wire, not enclosed as above, without being permanently separated therefrom by some continuous and firmly-fixed non-conductor. The non-conductor used as a separator must be in addition to the regular insulation on the wires. Where tubes are used, they must be securely fastened at the ends to prevent them from moving along the wire.

Deviations from this rule may, when necessary, be allowed by special permission.

The reasons for the separation of wires from everything but their insulating supports are many. Should a bare live wire come in contact with damp woodwork or masonry, there would very likely be some flow of current to ground and through the ground to the other pole of the dynamo or other wire. This flow of current may gradually char the woodwork, and in time start a fire; or it may gradually eat away the wire, finally causing it to break. When a wire is eaten away, as shown at *c* and *e*, Figure 67, if it is carrying much current, the thin part will become very hot and will set fire to whatever inflammable material may be near it. If the current flow to the ground continues, the positive wire will finally be entirely severed, and an arc, similar to that noticed in an ordinary arc lamp, will be established, and will continue until the wire has been burned away and the space between the two

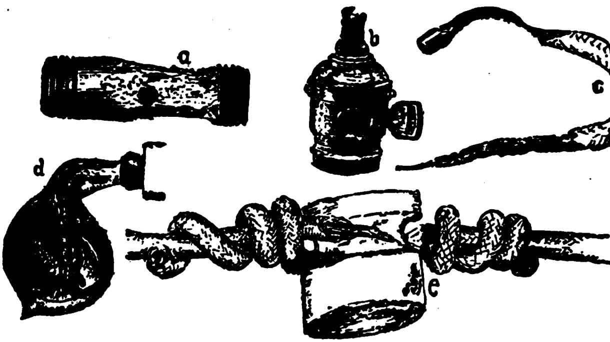


Figure 67.

ends becomes too great for the arc to maintain itself. The negative wire, to which the current flows, is not eaten away in this manner, and such current flow is only possible when two wires of a system are in electrical connection with the ground. This action may, however, occur, even if the two grounded wires are miles apart. Wires and gas pipes are often destroyed through intermittent contact; for instance, if a wire makes a good contact to a gas pipe and there is a small leak to the pipe no particular harm will be done as long as the contact remains good. Should, however, the contact be intermittent, there will be a small arc at each break, and this will, little by little, burn holes into the gas pipe and into the wire. This action will take place on either a positive or negative wire. Non-combustible supports for wires are further useful in that they tend to prevent flames from the rubber insulation (which is very easily ignited from any of the above causes, from spreading to surrounding material.

Figure 67 consists of copies of specimens showing effects of electrolysis, short circuits, and heating of lamp. These illustrations are copied from fire reports of the National Board of Underwriters.

At *a* is shown a piece of gas pipe, which had been subject to electrolytic action until finally a hole had been eaten through the metal; *b* is a socket which had been short circuited, and the excessive damage was due to overfusing of circuit.

At *c* and *e*, the effects of electrolysis on wire are shown; *c* is a piece of underwriter's wire (not approved in moulding), which had been used in damp moulding, the leak to ground through the dampness causing the gradual eating away of the wire; *c* shows a breakdown in the insulation and subsequent electrolytic action on the wire causing it finally to break. This wire had been used in a roundhouse, where the sulphur fumes and the condensation of escaping steam on insulators had formed a path to ground. At *d* is an incandescent lamp which had been covered with a towel, the confined heat softening the glass and setting fire to the towel. The danger of fire from overheated lamps is much greater than is generally supposed. Small lamps and lamps subject to a little excess of voltage are especially dangerous, and many instances are on record where they have charred woodwork and set fire to cloth or paper shades.

It may in many cases seem unnecessary to have bushings in one piece long enough to pass through a floor, or wide wall; but especially in passing through floors, it is easily possible for wires to become crossed between the joists; that is, the wire entering at the right above the floor may be brought out at the left below the floor and the other wire through the opposite holes. In such a case the two wires of opposite polarity will be in contact, and should the insulation give out from any cause whatever, such as abrasion, or the

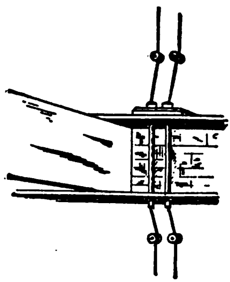


Figure 68.

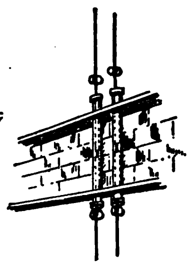


Figure 69.

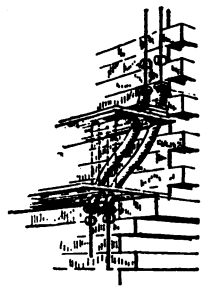


Figure 70.

gnawing of rats and mice, there would be nothing to prevent a short circuit and consequent fire. In passing through floors or walls the wires often come in contact with concealed pipes or other grounded material, so that only by making the bushings continuous as shown in Figure 68 can the wires be properly protected.

Figure 69 shows short bushings arranged in iron pipe. Figure 70 shows a case where there is an offset in the wall. Cases of this kind very often occur. Sometimes the floor can be taken up and an iron conduit, properly bent, put in place; the wires being reinforced with flexible tubing; or the wires placed on insulators. In this latter case the floor must not be put down until the inspector has examined the wires. The wires may be run on top of the floor to such a place where a continuous bushing may be dropped through the floor. The wires on top of the floor must be then protected by a suitable boxing of at least the same dimensions as given for boxing on side walls.

Caution must be observed in placing wires carrying alternating currents in single conduits or pipes. If the wires carry only a small amount of current no serious effects will result but if considerable current is flowing over the wires the pipes may become very hot. Where it is necessary to use pipe or conduit for bushings in such cases both wires should be placed in the same pipe.

Figure 71 is a sectional view of the manner in which wires are usually run through joists in bushings. For small wires

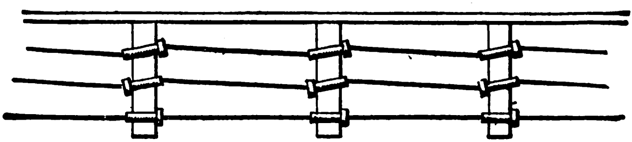


Figure 71.

bushings should preferably be installed as shown at top; never as shown in the middle row. For larger wires the holes must be bored as straight as possible; otherwise it will be difficult to pull wires through. The quantity of wire needed is also somewhat increased by slanting the holes. In open places wires are generally installed on insulators as shown in Figure 72.

Figure 72 shows different methods employed where one wire crosses another. The method at the left, which is more suited to large stiff wires, does not quite comply with the rule, but is very often used. The other two methods are preferable. Insulating supports should always be provided at the place of crossing to prevent the upper wires from sagging and resting on the lower; also to prevent any strain from coming on tap joints. Approved flexible tubing such as circular loom is also often used in crossing wires and pipes. In

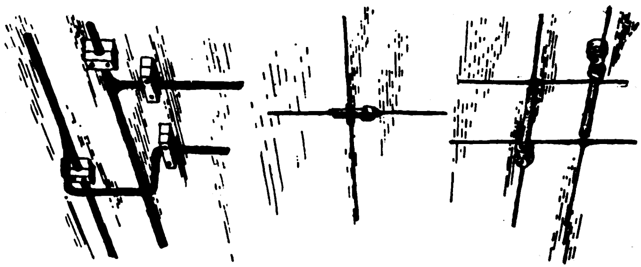


Figure 72.

dry locations it is quite safe and does not break as easily as tubes, but should never be used where there is any likelihood of dampness.

f. Must be so placed in wet places that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally. Wires should be run over rather than under pipes upon which moisture is likely to gather or which, by leaking, might cause trouble on a circuit.

This is a rule that is very often violated, as much work is done using loom, as shown at the left of Figure 73, and is quite safe with gas pipes. With cold water pipes, which are likely to sweat, or with steam pipes, it is very bad practice. Where pipes are close against a ceiling it is better either to fish over them or drop wires some distance below them as illustrated at the right of the figure. No part of the wiring should be in contact with pipes. On side walls where vertical wires run across horizontal pipes the only safeguard would be to box the pipes and run the moisture to one side. The most harm is done by water on the insulators. If these can be kept dry it does not matter much about wires which hang free in the air. Whatever form of insulation is used in crossing pipes, it must be continuous. Short bushings strung on the wire, where a large pipe or number of pipes are being crossed, is not satisfactory, as the bushings are apt to separate

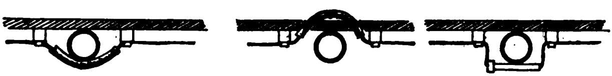


Figure 73.

or moisture gather in the space between them. The insulation must also be firmly attached to the wires. If knobs are not used as shown in Figure 72 to keep the bushings in place, they must be taped to the wire.

g. The installation of electrical conductors in wooden moulding, or on insulators, in elevator shafts will not be approved, but conductors may be installed in such shafts if encased in approved metal conduits, or armored cable.

Wires supported on insulators in such places are very likely to be disturbed, especially in freight elevators. Moulding is often so impregnated with oil and the draft in an elevator shaft is usually so strong that a blaze once started would quickly run to the top.

17. Underground Conductors.

a. Must be protected against moisture and mechanical injury where brought into a building, and all combustible material must be kept from the immediate vicinity.

b. Must not be so arranged as to shunt the current through a building around any catch-box.

By reference to Figure 74 the meaning of this rule will be made clear. With wire run as shown it would be easy for any one having disconnected one service switch to believe all wires in the building dead, while they were in reality still being kept alive by the other switch. This connection would allow current to pass from one street main to another without going through the fuses in the street catch-box.

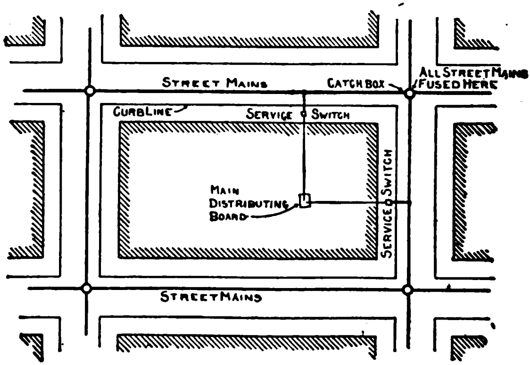


Figure 74.

c. Where underground service enters building through tubes, the tubes shall be tightly closed at outlets with asphaltum or other non-conductor, to prevent gases from entering the building through such channels.

d. No underground service from a subway to a building shall supply more than one building except by written permission from the Inspection Department having jurisdiction.

18. Table of Carrying Capacity of Wires.

(See tables in back of book.)

19. Switches, Cut-outs, Circuit-Breakers, Etc.

a. On constant potential circuits, all service switches and all switches controlling circuits supplying current to motors or heating devices, and all fuses, unless otherwise provided (for exceptions as to switches see Nos. 8 *c*, 25 *a* and 43 *c*; for exceptions as to cut-outs see No. 23 *a* and *b*, must be so arranged that the fuses will protect and the opening of the switch will disconnect all of the wires; that is, in the two-wire system the two wires, and the three-wire system the three wires, must be protected by the fuses and disconnected by the operation of the switch.

When installed without other automatic overload protective devices automatic overload circuit breakers must have the poles and trip coils so arranged as to afford complete protection against overloads and short circuits, and if also used in place of the switch must be so arranged that no one pole can be opened manually without disconnecting all the wires.

This, of course, does not apply to the grounded circuit of street railway systems.

The exceptions for switches are for motors of ¼ H. P. or less on circuits where the voltage does not exceed 300, electric heaters requiring not more than 660 watts and electric cranes. In the first two cases single pole switches may be used and in the case of cranes switches need not be provided for each individual motor. The exception for cut-outs is for mains where the fuse is omitted in the neutral wire.

In connecting double pole snap switches the wireman should be very careful. Most of these switches cross polarities as shown in Figure 75, and if connected wrong will form short circuits. Many of them have been connected this way even by wiremen of some experience.

b. Must not be placed where exposed to mechanical injury nor in the immediate vicinity of easily ignitible stuff or where exposed to inflammable gases or dust or to flyings of combustible material.

Where the occupancy of a building is such that switches, cut-outs, etc., cannot be located so as not to be exposed as above, they must be enclosed in approved dust-proof cabinets with self-closing doors, except oil switches and circuit breakers which have dust-tight casings.

Whenever an electric current is broken, whether by fuse or switch, an arc varying with the current strength is formed. Should a switch be only partly opened, this arc will continue and consume the metal of the switch until the gap in which it burns becomes too long, when the current will be broken.

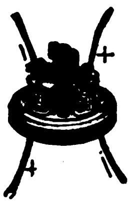


Figure 75.

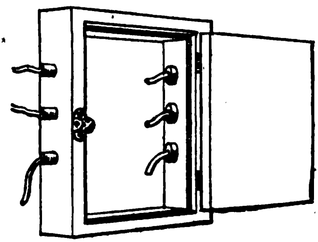


Figure 76.

Meanwhile there is much heat generated which may readily communicate to inflammable material near by.

There seems to be no reason except economy of wire why cut-outs should ever be placed inside of dust rooms. Switches of course must often be placed in such rooms, as in many cases the entire building outside of the engine room is dusty. In such cases the switches as well as the cut-outs may, however, be often placed on the outside walls convenient to some window.

An approved cabinet is shown in Figure 76. If used in connection with knife switches it should be large enough to admit being closed when the switch is open. In cases where cut-outs and switches must be located in dusty rooms, it would be well to construct double cabinets, one part for the cut-outs and another for the switches. The fuses, which are the most dangerous, can then be tightly enclosed, as it will seldom be necessary to get at them. In practice it has been found almost impossible to keep the doors of cabinets which are much used closed. It seems next to impossible to construct a cabinet which is dustproof, with a door that can be readily opened, and a self-closing door can hardly be made to remain dustproof. Doors are made self-closing either through gravity or by suitable springs.

As switch and cut-out boxes are very likely to be used for the storage of cotton waste, paper, etc., which would readily

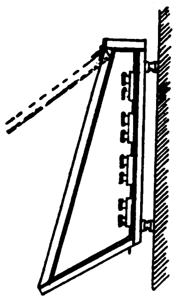


Figure 77.

ignite from a melted fuse, it would be well to construct them with a slanting bottom as indicated in Figure 77, so that nothing will lie in them.

A cut-out box of very good design is shown in Figure 77. The door closes by gravity and the manner in which it lies against the cabinet causes it to close more securely than it would if hung perpendicularly.

c. Must, when exposed to dampness, either be enclosed in a moisture-proof box or mounted on porcelain knobs. The cover of the box must be so made that no moisture which may collect on the top or sides of the box can enter it.

Figure 77 is a sectional side view of a cut-out box for use out of doors. It is mounted on porcelain knobs. In all damp places much trouble is experienced from leakage through the moisture on the surface of the slate or marble and through the wax used to cover the bare parts on back of switch.

In locations where moisture is always present an incandescent lamp burned in the cut-out box will tend to keep it dry. This system has been used in packing houses and has proven very satisfactory.

d. Time switches, sign flashers and similar appliances must be of approved design and enclosed in an *approved* cabinet.

Special attention should also be given to the location of such switches and flashers. They are often left without care, the blades, wear down and the arcing continues through bad contacts. Often springs become weak and no longer break the circuit properly.

Time switches are usually operated by clockwork, the clock releasing a spring which throws the switch on or off as may be required and pre-determined. Complete diagrams of sign flashers are given in *"Modern Wiring Diagrams and Descriptions"* and will not be repeated here.

CONSTANT-CURRENT SYSTEMS.

Principally Series Arc Lighting.

(See also Nos. 16, 17, 18 and 44. For construction rules, see Nos. 49 and 50.)

20. Wires.

a. Must have an *approved* rubber insulating covering.

b. Must be arranged to enter and leave the building through an *approved* double-contact service switch mounted in a non-combustible case, kept free from moisture, and easy of access to police or firemen.

In order that all of the wiring in the building may be entirely disconnected a switch, the principle of which is illus-

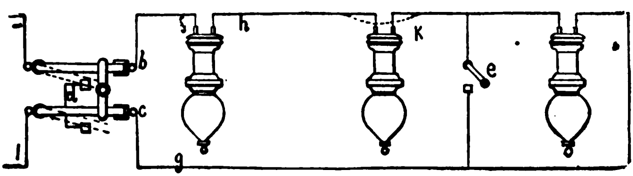


Figure 78.

trated at *d*, Figure 78, is provided where wires enter and leave the building. A modern commercial form of this switch is shown in Figure 79. This switch never breaks the circuit. As shown in Figure 78, the current passes from the positive poles, through the upper blade of the switch to *b* and thence through the arc lamps back to *c* and to the negative pole. When it is desired to extinguish the lamps the two blades of the switch are moved downward, as indicated by the dotted lines. The contacts *d* are arranged so that both switch blades connect with them before disconnecting entirely from the points *b* and *c*. As soon as both blades are in contact with *d* all current flows through it because the resistance of it is so very much less than that of the lamps. With the switch in the position indicated by dotted lines, the current still flows in the outside wires, but all wires within the building are "dead." At *e*, Figure 78, is shown a single-pole switch which operates on the same principles as the other. If this switch is closed all current will pass through it; if open the current will pass through the last lamp. A switch of this kind is always arranged within the lamp itself. This latter way of switching lamps should never be used, as a lamp switched in this way is never safe to handle. There is just as much danger from shocks when the lamp is switched off as when on.

Figure 79.

With switches as described above there is no spark whatever when lamps are switched off, but there is usually quite an arc when the lamps are switched in. Should there be a broken wire or a lamp out of order in the circuit to be switched in, there will be quite an arc maintained for some time. In such a case the switch should be quickly closed and the trouble located.

In handling live wires of this system great care is necessary. The wireman should insulate himself from the ground by a dry board, or, if all about him is damp, by a board resting on insulators. Rubber gloves and rubber boots, if kept dry, are useful.

Death or bad burns may result if the wireman, standing on wet ground or any conductor in connection with it, touches part of a circuit which is also partly in connection with the ground. If, in Figure 78, the wire at *f* is grounded, a man in connection with the ground and touching a bare wire at *h* will receive a shock due to about 50 volts, but if he touches the wire at *g* he will receive a shock of about 150 volts. The shock received from a line containing 100 lamps may be anything from 50 to 5,000 volts, and may result in only a slight burn or in instant death.

Another danger in connection with live circuits is the liability of cutting oneself into circuit. If one is perfectly insulated from the ground there is no harm whatever in touching one live wire (with very high voltages such insulation is, however, hard to obtain) with either one or both hands while the wires are in order. Should, however, the wire between the two hands break, the current would immediately pass through the body, very likely causing instant death. Even if the circuit is not entirely broken, if only a resistance is cut in, the shock will be very severe. As, for instance, if one should touch the terminal of an arc lamp, not burning, with each hand nothing whatever would be felt, but, if the lamp were now suddenly switched on, there would be a very severe shock at first, which would become less so when the lamps were fairly started. To avoid the possibility of such occurrences when working on live lamps or circuits a short wire known as a "jumper" is often connected, as at *k*, Figure 78. This will carry all current, and there is now no danger except from a connection to ground.

c. Must always be in plain sight, and never encased, except when *required* by the Inspection Department having jurisdiction.

What is known as concealed knob and tube work is not allowed in wiring for high tension arcs; neither can the wires be run in moulding or conduit.

It has been customary to use no smaller than No. 6 wire for these high tension series circuits. The current required is seldom more than 10 amperès, and No. 14 wire has sufficient carrying capacity, but its mechanical strength is not very great. The danger from a broken wire in high tension systems is much greater than in low tension systems, because of the long arc which occur at the break. The loss in volts per 100 feet with No. 6 will be about .4; while with No. 14 it will be 2.6. While this will not affect the lights, the pressure at the generator being correspondingly increased, the question of drop is of importance. On a circuit 10 miles long a No. 14 wire would have a drop of 1372 volts and a No. 6 wire a drop of 211 volts.

d. Must be supported on glass or porcelain insulators, which separate the wire at least one inch from the surface wired over, and must be kept *rigidly* at least eight inches from each other, except within the structure of lamps, on hanger-boards or in cut-out boxes, or like places, where a less distance is necessary.

An extra precaution often taken in this kind of work on plastered walls is to place a wooden block or rosette about three inches in diameter and one-half inch thick under each insulator; this secures greater separation from ceilings and side walls and adds greatly to the stability of the insulators. On plastered walls a small insulator, if subjected to side strain, will cut into the plaster on one side and allow the wires to sag; the wooden block will prevent this.

e. Must, on side wall, be protected from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than seven feet from the floor. When crossing floor timbers in cellars, or in rooms where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness. Instead of the running-boards, guard strips on each side of and close to the wires will be accepted. These strips

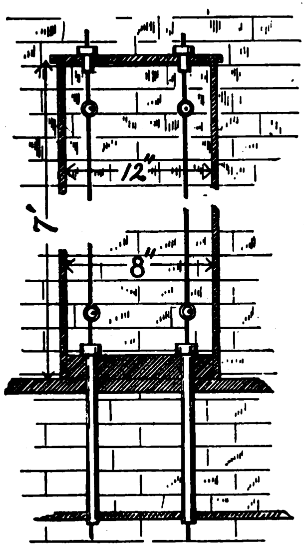


Figure 80.

to be not less than seven-eighths of an inch in thickness and at least as high as the insulators.

Figure 80 is an illustration of protection on side walls, giving the dimensions required for high tension. The wooden block shown, which raises bushings above floor, is an extra protection to prevent water from running into them.

21. Series Arc Lamps.

(For construction of Arc Lamps, see No. 74.)

a. Must be carefully isolated from inflammable material.

b. Must be provided at all times with a glass globe surrounding the arc, and securely fastened upon a closed base. Broken or cracked globes must not be used.

c. Must be provided with a wire netting (having a mesh not exceeding one and one-fourth inches) around the globe, and an *approved* spark arrester (see No. 75), when readily inflammable material is in the vicinity of the lamps, to prevent escape of sparks of carbon or melted copper.

Outside arc lamps must be suspended at least eight feet

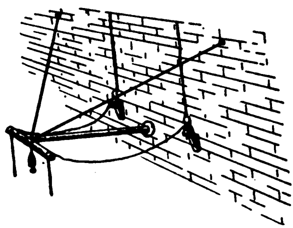


Figure 81.

above sidewalks. Inside arc lamps must be placed out of reach or suitably protected.

Arc lamps, when used in places where they are exposed to flyings of easily inflammable material, must have the carbons enclosed completely in a tight globe in such manner as to avoid the necessity for spark arresters.

"Enclosed arc" lamps, having tight inner globes, may be used, and the requirements of Sections *b* and *c* above would, of course, not apply to them.

d. Where hanger-boards are not used, lamps must be hung from insulating supports other than their conductors.

e. Lamps when arranged to be raised and lowered either for carboning or other purposes, shall be connected up with stranded conductors from the last point of support to the lamp, when such conductor is larger than No. 14 B. & S. gage.

Figure 81 shows the usual method of suspending outdoor arc lamps on buildings. The supporting wire may be fastened to brick or stone walls by drilling a hole about four inches deep and plugging this securely with wood, when an eye or lag bolt or large spike may be driven or screwed into it. Expansion bolts, of which there are many kinds to be had, may also be used and are preferable in most cases. It is best to arrange the supporting wires at quite a high angle, otherwise the direct outward pull may be too great.

On very low ceilings, lamps are often arranged as shown at Figure 82, the plastering being cut away and lamp sus-

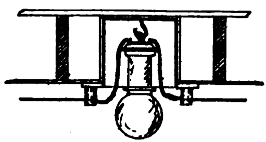


Figure 82.

pended from floor above joists. The space above plaster must be enclosed on all sides and all woodwork protected with asbestos board at least one-eighth inch thick.

If this method is used with constant potential arc lamps carrying resistance in the hood, it would be well to remove or short-circuit this resistance and locate another in a more suitable place.

A stranded wire is required for lamps that are to be raised or lowered as the constant movement of the wires due either to the raising or lowering of the lamp for recarboning or the swinging of the wires by the wind is liable to cause them to break and form an arc inside the insulation.

22. Incandescent Lamps in Series Circuits.

a. Must have the conductors installed as required in No. 20, and each lamp must be provided with an automatic cut-out.

b. Must have each lamp suspended from a hanger-board (see No. 73) by means of rigid tube.

c. No electro-magnetic device for switches and no multiple-series or series-multiple system of lighting will be approved.

d. Must not under any circumstances be attached to gas fixtures.

Some years ago carbon filament series incandescent lamps were frequently used for street lighting, especially in small towns and in the residence districts of cities. These lamps were operated in series direct from the primary circuits with either automatic cutouts at the lamps or an arrangement in the plant whereby additional lamps could be switched in on the circuit as lamps burned out on the line. They were also operated in connection with series arc lamps on the same circuits. They were seldom used for inside lighting. None of these systems proved very satisfactory.

With the advent of the tungsten lamp the use of series lighting has greatly increased for the purposes mentioned. These lamps may be obtained of various candle powers and are made with a very rugged filament. They are operated in series on alternating current circuits with current transformers or current regulators.

Each lamp is inserted in a special socket such as is shown in Figure 83. The socket is constructed of porcelain so that it is perfectly weatherproof and is provided with a pair of metal prongs arranged to fit into the receptacle as shown. Inserted between the prongs is a thin film of shellac or mica. Current flows from the contacts on the receptacle through one of the prongs to the lamp and out through the other prong. If the lamp burns out an excessive voltage is impressed on the terminals and the insulating film is broken down the circuit being then completed directly through the metal prongs.

The socket may be removed from the receptacle in which case the circuit closes automatically by the spring clips of the receptacle coming together. A new lamp may then be inserted and a new film placed between the prongs and the lamp then put in service. Removing the lamp from the socket allows the spring contact inside the socket to close the circuit so that the

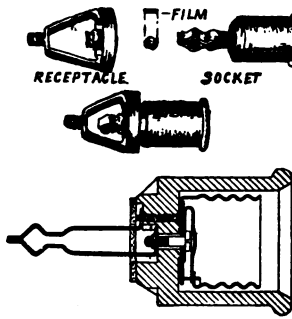


Figure 83.

lamps may be changed at will. The automatic film will break down at a potential of about 400 volts.

The same precautions for handling these circuit must be observed as mentioned in the case of series arcs.

Considerable discussion has arisen at times in regard to the rule restricting series-multiple or multiple-series systems of lighting. This rule has been applied to low potential systems circuits but it will be noted that it comes under the head of constant current systems (principally series arc lighting) and was not intended to refer to the ordinary low potential systems.

The table given below gives data on the Mazda Street series lamps.

MAZDA STREET SERIES LAMPS.

Ampere Range	Candle-power	Average Total Watts	Average Volts	W. P. C.	% Spherical of Horizontal Candle-power	Total Lumens	Hours Life
4.0 (3.9 to 4.3)	32	37.8	9.5	1.18	78.3	315	1350
	60	70.8	17.7	1.18		590	
	100	118.0	29.5	1.18		984	
	200	236.0	59.0	1.18		1968	
	350	413.0	103.3	1.18		3443	
5.5 (5.1 to 5.9)	32	37.8	6.9	1.18	78.3	315	1350
	60	70.8	12.9	1.18		590	
	100	118.0	21.4	1.18		984	
	200	236.0	42.9	1.18		1968	
	350	413.0	75.1	1.18		3443	
6.6 (6.1 to 6.9)	32	37.8	5.7	1.18	78.3	315	1350
	60	70.8	10.7	1.18		590	
	100	118.0	17.9	1.18		984	
	200	236.0	35.8	1.18		1968	
	350	413.0	62.6	1.18		3443	

CONSTANT-POTENTIAL SYSTEMS.

General Rules—All Voltages.

23. Automatic Cut-Out (Fuses and Circuit-Breakers).

(See also No. 19. For construction rules see Nos. 66 and 67.)

The fuse is the principal protective device used in electric light and power work. In its simplest form it consists of a piece of wire made of a certain alloy designed to melt at a comparatively low temperature. It is so connected in the circuit that all the current must pass through it. We have already seen that currents of electricity generate heat in the conductors through which they pass, and that this heat is proportional to the square of the current flowing; that is, if we double the current we shall increase the production of heat fourfold. A dangerous rise in current strength may be due to a "short circuit" or to an overload, too many lamps or motors being connected to a circuit. To prevent damage to wires and other apparatus from excessive currents, fuses or cut-outs must be installed. When the current rises above its allowed strength the fuse melts and opens the circuit; that is, stops all current flow. The melting of the fuse is accompanied by a flash of fire due to the arc which is set up across the break in the fuse wire. On an ordinary overload with the smaller size fuses this arc may not be very severe, but with the larger size fuses and on short circuits a very severe flash and explosion may result and molten metal may be thrown for some distance from the fuse. This explosion is caused by the outer layers of metal of the fuse remaining cool and in a solid state while the metal at the center of the fuse is first melted and then vaporized.

Another device which is used for the same purpose as the fuse is known as the circuit-breaker. A circuit-breaker in its simplest form comprises a knife switch which when closed is forced in against a spring and held in place by means of a small catch. A solenoid, inside of which is placed a moveable iron core, is connected in series with one side of the switch. When the current passing through this solenoid exceeds a certain amount, the iron core is drawn up into it, and, striking against the catch, releases the switch which will then fly open, thus cutting off the current. The core of this solenoid is so designed that when it starts to move its speed is greatly accelerated so that it strikes the catch a sharp blow. By means of a small adjusting screw the circuit-breaker can be set to operate at various current strengths within its limits. For this reason and for the further reason that it is so easily made inoperative by tying or blocking its solenoid it is not approved for general use unless fuses are also installed. It may be used under the care of a competent electrician who understands the dangers of its abuse.

Under these conditions its use is to be strongly recommended. Where not so used fuses must also be provided in the same circuit with the circuit breaker. For further information in reference to the use of circuit breakers see section on Generators, Page 58.

a. Must be placed on all service wires, either overhead or underground, in the nearest accessible place to the point where they enter the building and inside the walls, and arranged to cut off the entire current from the building.

Where the switch required by No. 24*a* is inside the building, the cut-out required by this section must be placed so as to protect it.

For three-wire (not three-phase) systems the fuse in the neutral wire may be omitted, provided the neutral wire is of equal carrying capacity to the larger of the outside wires, and is grounded as provided for in No. 15.

In risks having private plants, the yard wires running from building to building are not considered as service wires, so that cut-outs would not be required where the wires enter buildings, provided that the next fuse back is small enough to properly protect the wires inside the building in question.

The fuse block here required serves a double purpose; it affords protection to the whole installation while in use, and is an effective means of disconnecting a building when current is no longer used. This can also be accomplished by means of the service switch, but a switch is so easily closed by any one that it must never be relied upon entirely for this purpose.

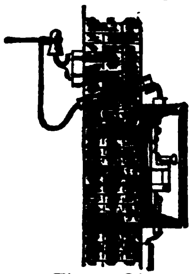


Figure 84.

Figure 84 shows arrangement of fuses and switch as commonly installed where wires enter buildings. The wires enter at the top, connect to the fuse terminals, current passing through the fuses to the switch.

This rule allows the neutral fuse to be omitted on three-wire systems where the neutral is grounded and where the neutral wire is of as great carrying capacity as the larger of the outside wires. On three-wire systems where the neutral wire is not grounded, as in the case of some isolated plants, fuses must be placed in all three wires, including the neutral wire. The reason for this is obvious. A ground coming on any part of the neutral wire of a three-wire grounded system cannot cause a short circuit. Referring to Figure 85, G shows the permanent ground and B a ground on any other point on the neutral wire. It is plain that the ground B cannot cause a short circuit, and the fuse in this wire may, therefore, be omitted. A ground coming on either of the outside wires, at A for instance, would be cleared by the fuse protecting that wire. In a system with an ungrounded neutral a single ground coming on one of the outside wires, as at G′ for instance, would not cause a short circuit, but if the outside wire was grounded at G′ and a ground should come on the neutral wire, at B for instance, a short circuit would immediately result and the neutral wire would probably be destroyed owing to the fact that there is no fuse to protect it.

If the fuse is omitted in the neutral wire and a fuse on one of the outside mains should blow, the neutral wire would then be called upon to carry the same amount of current as was being carried in the remaining outside wire. For this

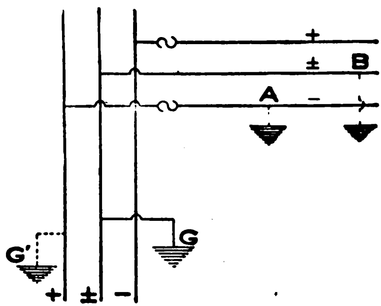


Figure 85.

reason the neutral wire must be of as great carrying capacity as the larger of the outside wires.

The danger arising from the blowing of the neutral fuse (which this rule is designed to prevent) is described under the next rule, 23 *b*.

b. Must be placed at every point where a change is made in the size of wire [unless the cut-out in the larger wire will protect the smaller (See Table of Carrying Capacity)].

For three-wire direct current or single phase systems the fuse in the neutral wire except that called for under No. 23 *d*, may be omitted, provided the neutral wire is grounded as provided for in No. 15.

Figure 86, A to D, shows systems of distribution and arrangement of mains in general use. Figure A shows the simplest and cheapest method of running mains, and is known as the "tree system." Beginning at the service the wires must be large enough to carry the whole amount of current used to the first floor or wherever the first cut-out center is located. At this point the size of wire may be reduced because it will be required to carry only the current used further on. Main cut-outs should be arranged as shown in the figure at 1 and 2. That is, the cut-outs protecting the mains must be installed in the mains at each floor after the current for that floor has been taken off. Cases are often found where the cut-out is placed in the main line, ahead of the branch blocks. This is obviously wrong, as the fuse will have to be too heavy to protect the smaller mains.

Figure B shows a somewhat different arrangement which requires more wire and is more expensive in the beginning, but far more satisfactory and economical in operation. With the wires arranged as shown in the diagram the pressure at all the lamps will be nearly uniform. Even if the mains are designed for a considerable loss to the center of distribution the dynamo may be made to compensate for this loss and keep the lamps burning properly. With the tree system, A, this is impossible; the lamps at the first cut-out center will either be too bright or those at the last center too dim.

Figure C shows a convertible three-wire system.

In order to convert a three-wire system into a two-wire system the two outside wires are joined together. The middle wire then forms one side of the system and the outside wires the other. The middle wire must carry as much current as both outside wires combined and should have a carrying capacity equal to them. It should be remembered that a

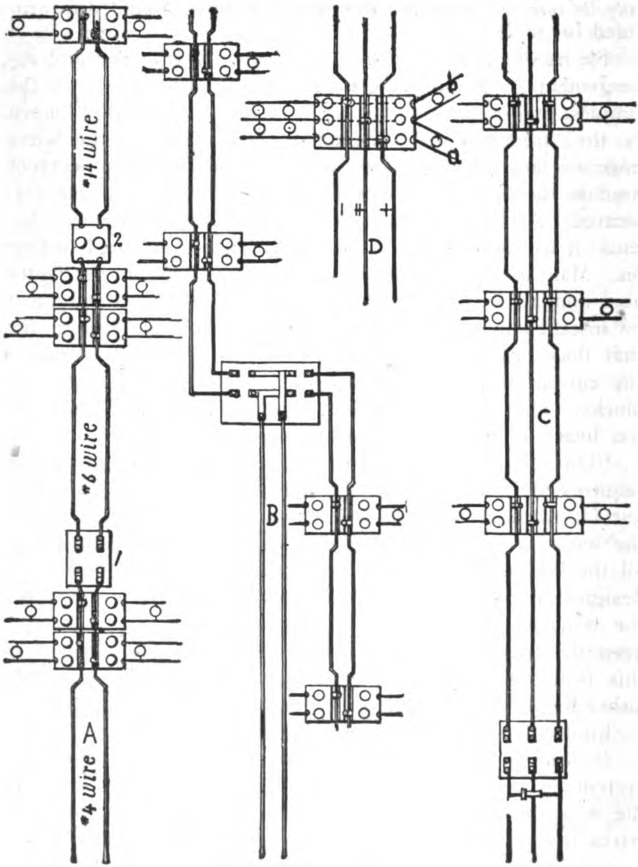


Figure 86.

wire containing simply twice as many circular mils does not fulfill this requirement, as is shown in Table No. 2 on page 421, which must be consulted in selecting wires.

In three-wire systems the middle or neutral wire is merely a balancing wire and normally carries very little or no current, but it is very important that it remain intact. If for instance in Figure D the branch circuit *a* has twelve lights burning while there are also twelve lights burning on *b*, the current will pass from the positive wire through the lower fuse to *a*, through the twelve lights in *a* back to the middle fuse, thence through the twelve lights in *b* to the upper fuse and negative wire, the two sets of lamps burning in series. If now the lamps in *b* are switched off the current from *a* can no longer pass through them and instead returns through the middle fuse to the neutral wire. If only six lights in *b* are burning, while twelve are burning in *a*, the current of six lights will return over the negative wire and the other six in *a* will return over the neutral wire. Should the neutral wire be broken or its fuse blown there would be no return path on it for the extra current, and consequently the current passing through the twelve lights in *a* would be forced to pass through the six lights in *b*, causing them to burn with excessive brilliancy and to break in a very short time. Should a short circuit occur, say on circuit *b*, with the neutral wire intact, it would merely blow out a fuse, but if the main neutral fuse were out it would bring 220 volts on circuit *a* and speedily cause damage to the lamps. Thus it will be seen that it is of great importance to fuse the neutral wire so that it will not easily blow out.

Figure C shows a system of wiring quite often used. A set of heavy mains are run from the service or dynamo to the top floor and taps taken off at each floor. These mains do not change size at each floor, but are continuous for their entire length. While this method has some of the objections of the tree system in regard to voltage, still the faults of the tree system are greatly reduced owing to the much smaller losses in the mains between the upper floors, or those farthest

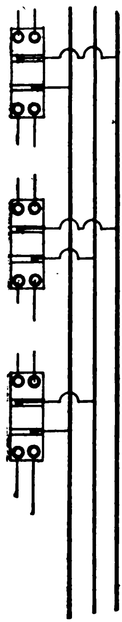


Figure 87.

from the dynamo. Figure 87 shows a set of three-phase risers with branch circuit taps.

Figure 88 shows the method of fusing main switch and branch circuits. The switch itself will require a fuse to protect it, although it need not be right at the switch.

It often becomes necessary to reinforce a set of mains, especially for motors, which have become overloaded, by running another wire in parallel with the old, as indicated in Figures 89 and 90. Two separate and distinct ways of arranging them are shown and it depends upon the conditions as to which is preferable. If the wires are small or run in places where they are liable to be broken, the plan shown in Figure 89 is the better. Here each wire is properly fused and one breaks the other carries the whole load until its fuse ts. If the wires, as often happens, are much overfused, r breaking of one wire would force the other to carry whole current and become overheated. If the arrange-

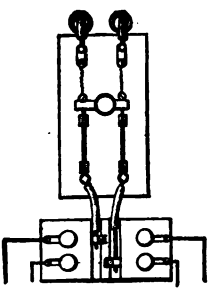


Figure 88.

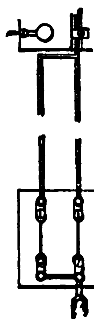


Fig. 89.

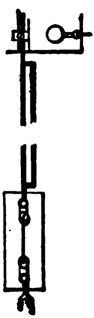


Fig. 90.

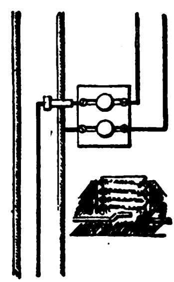


Figure 91.

ment were as in Figure 90 the unbroken wire would carry the current indefinitely and soon become overheated. On the other hand, if both wires are large and the run is short the fuses arranged as in Figure 89 may, through poor contacts, prevent one or the other of the wires from obtaining its full share of the current. The fuse making poor contact would force a much greater share of current through the other wire. In most cases the better plan would be to arrange the wires as in Figure 90. If the current supplied is for lights the branch cut-outs can be separated and each set of mains allowed to supply a certain part of them, when each set should be made independent. For sizes of wires to be used for reinforcing, see Tables.

With the three-wire system where a large motor load and but few lights are used the lights are often fused as shown

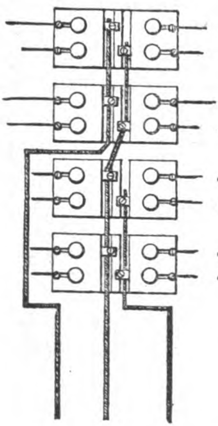


Figure 92.

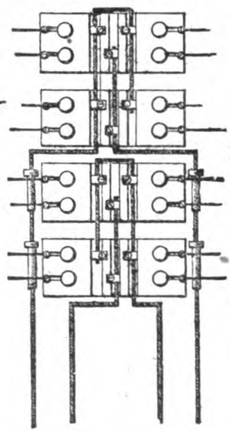


Figure 93.

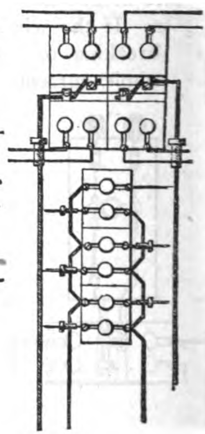


Figure 94.

in Figure 91, a small wire being run for the neutral, this smaller wire, of course, being properly fused at the main cut-out. Plug cut-outs of the type shown in this figure often have the metal parts projecting above the porcelain; they should be connected so that the metal parts which project are dead when the plugs are removed. This will prevent many short circuits on disconnected cut-outs.

Figure 92 shows the method of converting a two-wire system into a three-wire system with one extra wire to run. This extra wire will very likely not need to be as large as the other wires are, because the three-wire system requires only one-half as much current and it should, therefore, be used as the neutral. This arrangement will secure the full benefit of all the copper in the old wires (which are probably much larger than necessary) and will operate at a very small loss.

Figure 93 shows a straight three-wire system changed to a two-wire system, one extra wire run for it. If the three wires are of the proper capacity the addition of the fourth wire as in the figure will make it correct for two-wire systems, the mains feeding the upper and lower groups being, of course, properly fused where they start.

In Figure 94 the cut-outs are so connected that all branch wires leaving the cut-out box at either side are of the same polarity. This is often useful where many wires are to be run close together.

Connections to three-phase systems are made as shown in Figures 95 and 96.

Figure 95 shows the proper method of connecting plug cut-outs in "delta," and Figure 96 the connections for "star."

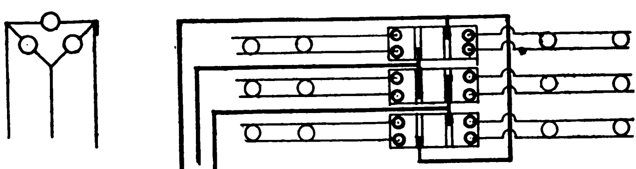


Figure 95.

The broken line indicates a balancing wire the office of which is somewhat similar to that of the neutral wire in a three-wire system. There are many cases in use where three-phase systems are connected in precisely the same manner as the ordinary three-wire system but this is decidedly wrong although in certain cases it may work fairly well.

c. Must be in plain sight, or enclosed in an *approved* cabinet, and readily accessible. They must not be placed in the canopies or shells of fixtures.

Link fuses may be used only when mounted on *approved* slate or marble bases and must be enclosed in dust-tight, fireproofed cabinets, except on switchboards.

Edison plug cut-outs and enclosed cartridge fuses are not required by the rule to be enclosed in cabinets unless exposed

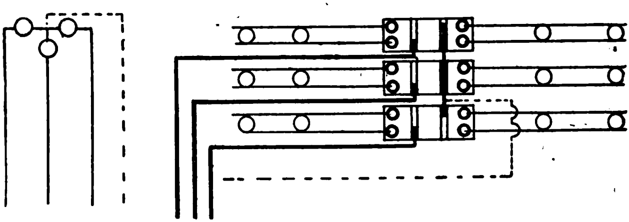


Figure 96.

to mechanical injury or close to easily ignitable material or where exposed to inflammable gases or dust or flyings of combustible material. Many cities, however, require the enclosing of these fuses and it is good practice to place all fuses in cabinets.

Where this is not done the rule should be strictly enforced as the older types of plug fuses with removable caps, and there are many still in use, become, with the cap removed, in reality open link fuses. Cartridge fuses are very frequently re-fused with fuse wire and the material from the inside of the fuse removed. They are also frequently re-fused with larger fuse wires than designed for and in numerous cases are found with fuse wire or other metal placed across the clips.

While it is required that cut-out cabinets be accessible there is also danger in making them too accessible, for such cabinets are very often used for storage of paper or cotton waste. It would seem that about seven feet above the floor is the most desirable height to place them or the cabinet may be arranged with a slanting bottom which will make it impossible to store anything in it. It is also well to locate the cut-out cabinet away from inflammable material, for long experience has shown that doors are nearly always left open. Especially is this the case when switches are in the same cabinets with the cut-outs.

d. Must be so placed that no set of incandescent lamps requiring more than 660 watts, whether grouped on one fixture or on several fixtures or pendants, will be dependent upon one cut-out.

Special permission may be given in writing by the Inspection Department having jurisdiction, for departure from this rule, in the case of large chandeliers. (For exceptions, see rule on theatre wiring.) All branches or taps from any three-wire system which are directly connected to lamp sockets or other translating devices, must be run as two-wire circuits if the fuses are omitted in the neutral, or if the difference of potential between the two outside wires is over 250 volts, and both wires of such branch or tap circuits must be protected by proper fuses.

The above shall also apply to motors, except that small motors may be grouped under the protection of a single set of fuses, provided the rated capacity of the fuses does not exceed 6 amperes.

The fuses in the branch cut-outs, except for motors as noted above, must not have a rated capacity greater than that given as follows for circuits at various potentials.

55 volts or less	12 amperes
Over 55 but less than 125 v.	6 amperes
125 to 250 volts	3 amperes

For sign and outline wiring supplied by circuits of 55 volts or less, branch circuit fuses of 25 ampere capacity may be used.

On open work in large mills *approved* link fused rosettes may be used at a voltage of not over 125 and *approved* enclosed fused rosettes at a voltage of not over 250, the fuse in the rosettes not to exceed 3 amperes, and a fuse of over 25 amperes must not be used in the branch circuit.

The final circuit to which incandescent lamps are connected must never (except as noted) supply a greater load than 660 watts. This limit has been determined by years of experience and it should never be exceeded. If a circuit is overfused, even though the wire supplying it may be of large carrying capacity, a short circuit in a piece of flexible cord or a brass shell socket may produce arc enough to cause a fire, and it must be remembered that a short circuit in a circuit protected by a six ampere fuse is much more severe where it occurs in a conductor of small capacity such as a flexible cord than it is in a conductor of greater capacity such as a No. 14 wire.

The limit of the circuit being 660 watts some departments allow 13 lamps per circuit on the assumption that the ordinary 16 candle power lamp requires only 50 watts. The more common practice is to allow 12 lamps per circuit, figuring each lamp as taking 55 watts.

The exception to the rule allow more lights on theater borders and large chandeliers. Theater borders are almost universally wired with either No. 14 or No. 12 standard wire and porcelain sockets so that a short is less liable to occur and is not so apt to result seriously. Large chandeliers,—such as are used in churches, are never equipped with key sockets and all the lights on each circuit are switched on at one time. Under this condition the maximum current is always flowing through the fuses and but a slight excess is necessary to blow a fuse. The arc produced from a short is, therefore, much less destructive than in the case, for instance, of only one lamp burning on a circuit protected by a six ampere fuse.

The rule allows three-wire branch circuits on systems where the neutral mains are fused and where the voltage does not execeed 250 volts. All other branch circuits must be two-wire and must have a fuse for each wire. Where three-wire branch circuits are used all three wires must be protected by fuses.

Small motors may be grouped on one circuit if they do not require more than six amperes. Considerable discretion should be exercised in determining the number of motors to allow on one circuit under this rule as the starting current must be taken into consideration and not the normal current. It is difficult to specify the exact number of motors which may be allowed on a circuit under the rule as small motors have a very low and varying efficiency and, in the case of alternating current motors, sometimes take large starting currents. So-called 1/6 horse power motors will often blow a six ampere fuse. The safest procedure is to try out the motors under the condition of maximum load and if a six ampere fuse will hold them they will come within the rule.

It will be noted that for systems of 55 volts or less not larger than 12 ampere fuses may be used on branch lighting circuits. Twenty-seven and one-half volt systems are used to some extent with tungsten lighting and the rule allows only 330 watts on a circuit. This lower current limit is specified for general lighting circuits (exception is made for electric signs), to allow the use of the general class of fittings which are not made for large current capacities.

e. The rated capacity of fuses must not exceed the allowable carrying capacity of the wire as given in No. 18. Circuit-breakers must not be set more than 30 per cent above allowable carrying capacity of the wire, unless a fusible cut-out is also installed on the circuit. Where rubber-covered wire is used for the leads or branches of A. C. Motors of the types requiring large starting currents, the wire may be protected in accordance with Table B. of No. 18, except when circuit breakers are installed which are equipped with time element devices.

Fixture wire or flexible cord of No. 18 B. & S. gage, will be considered as properly protected by 6 ampere fuses.

Fuses are designed to blow at a current 25% in excess of their rated capacity (see 68 b and c). Circuit breakers are, therefore, allowed to be set at 30% over the allowable carrying capacity of the wire. If fuses of the proper size are provided in the circuit, circuit breakers may be set at any point desired.

For alternating current motors requiring large starting currents the wires may be fused in accordance with the table of carrying capacity for "other insulations," this allowing an overfusing where rubber covered wire is used of about 50% for this class of service.

A circuit breaker equipped with a time element device will allow a considerable overload to flow for a short period of time. After this time has elapsed the breaker will operate at the current for which it is set.

f. Each wire of motor circuits, except on main switchboard or when otherwise subject to competent supervision, must be protected by an *approved* fuse whether automatic overload circuit breakers are installed or not. Single phase motors may have one side protected by an *approved* automatic overload circuit breaker only if the other side is protected by an *approved* fuse. For circuits having a maximum capacity greater than that for which enclosed fuses are approved circuit breakers alone will be approved.

The term "competent supervision" as applied to circuit breakers is often abused. A circuit breaker is so easily adjusted that there is a great temptation to set them too high for proper protection and they should not be allowed to be used without fuses in the circuit unless the person who has the supervision of them thoroughly understands the possible results which may follow their improper use.

24. Switches.

(See No. 19. For construction of Switches see No. 65.)

a. Must be placed on all service wires, either overhead or underground, in the nearest readily accessible place, to the point where the wires enter the building, and arranged to cut off the entire current.

Service cut-out and switch must be arranged to cut off current from all devices including meters.

In risks having private plants the yard wires running from building to building are not considered as service wires, so that switches would not be required in each building if there are other switches conveniently located on the mains or if the generators are near at hand.

In overhead construction the best plan is to locate the switch at either front or rear of building so that wires may lead to it direct from pole. Avoid running wires on sides of building where it is likely that other buildings may be erected. In underground construction, where the space under sidewalk and basement is not occupied, it is advisable to place a cut-out where wires enter the building from street and to locate the service switch in a more accessible place.

Although the rules do not call for switch to be installed in each separate building in the case of large plants, still it is often advisable to install them, for in case of trouble it is necessary that the current can be immediately shut off. A switch is also useful in cases of trouble on the wiring, to allow of repairing.

b. Must always be placed in dry, accessible places, and be grouped as far as possible. (See No. 19 *c.*) Single-throw knife switches must be so placed that gravity will not tend to close them. Double-throw knife switches may be mounted so that the throw will be either vertical or horizontal as preferred.

When practicable switches must be so wired that blades will be "dead" when switch is open.

When switches are used in rooms where combustible flyings would be likely to accumulate around them, they must be enclosed in dust-tight cabinets.

Up to 250 volts and thirty amperes, *approved indicating snap* switches are suggested in preference to knife switches on lighting circuits.

To comply with this rule will ordinarily bring the fuses of knife switches directly under the handle of switch. If there happens to be a short circuit on the wires when switch is closed the fuses will blow instantly and very likely burn the operator's hand. In connection with such switches cartridge fuses should be used or the switches, especially the

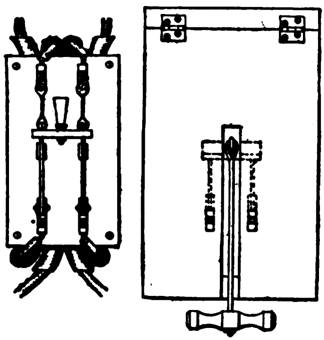


Figure 97.

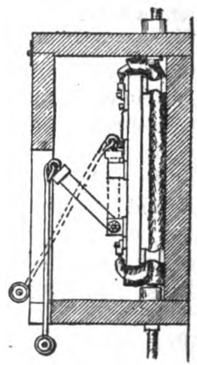


Figure 98.

larger ones, closed by pushing them in with a stick. The danger from opening a switch is much less.

Figure 97 shows a switch arranged to comply with all three points of this rule, the feed wires coming from below. This requires that incoming and outgoing wires pass each other. In this case, the wires pass each other behind the switch base, they being encased in flexible tubing. A side view is also given in Figure 98. Instead of passing behind the switch the wires may, of course, run around one side to the top, the other wires around the other side to the bottom.

Figure 98 illustrates a cabinet so arranged that the switch within can be opened or closed without opening the cabinet. The cover is hinged at the top, and slotted in the center, which leaves room for the lever by which the switch is worked to adjust itself so it will always be out of the way. A switch which is often used may as well be left without a cover as with one, for the door must be opened or closed every time the switch is used, and the cabinet will always be found open. Figure 98 will answer where only protection against accidental contacts is required.

c. Single pole switches must never be used as service switches nor for the control of outdoor signs nor placed in the neutral wire of a three-wire system, except in the two-wire branch or tap circuit supplying not more than 660 watts.

This, of course, does not apply to the grounded circuits of Street Railway systems.

Three-way switches are considered as single pole switches.

This rule allows the use of single pole switches (except for service switches and the control of outdoor signs) on circuits of 660 watts, 6 amperes at 110 volts, or 3 amperes at 220 volts, which corresponds roughly to twelve 16 c. p. lamps. In systems that are not grounded a single pole switch will answer fairly well if large enough. It will readily open the

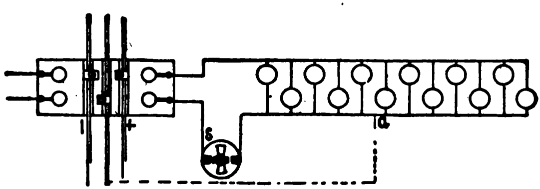


Figure 99.

circuit and it offers no opportunities for short circuits, as do double pole switches. Where, however, three-wire systems with grounded neutrals are used double-pole switches are preferable, for by reference to Figure 99 one can readily see that if the neutral or middle wire is grounded (which is equivalent to being in connection with gas piping) and another ground should come onto the wiring say at *a*, the single-switch, S, would not control the lights at all. The current would flow from the positive wire to the top fuse, through the twelve lights to ground *a*, through the ground to the neutral or middle wire and back to the dynamo, regardless of whether the switch is on or off. Also, a man working at the lights could easily make a short circuit by bringing the wires into contact with the gas piping even if the switch were turned off. When single-pole switches are used in connection with such circuits it is inadvisable to place them in the neutral wires as shown in the figure. If single-pole switch was placed in the upper wire in Figure 99 these troubles would be avoided. It is however often impracticable, in ordinary construction work to place single-pole switches in the outside wires, because these cannot be determined before connection and for this reason the requirement is waived. Where the time can be given it is always much better to avoid switches in the neutral wire and with some of the wires now on the market, where one wire of each duplex wire is marked it is an easy matter to accomplish this.

Three-way switches must not be used on circuits of over 660 watts. In wiring up three-way switches if both poles of the circuit are brought to the switch only one wire need be run between the switches, but where both poles of the circuit are connected into the switch the arc produced on operating the switch may carry from one pole to the other and cause a short circuit.

For full and comprehensive description of "three-way" switches the reader is referred to "Modern Wiring Diagrams and Descriptions" by the authors of this work.

d. Where flush switches or receptacles are used, whether with conduit systems or not, they must be enclosed in an *approved* box constructed of iron or steel, in addition to the porcelain enclosure of the switch or receptacle. No push buttons for bells, gas-lighting circuits, or the like shall be placed in the same wall plate with switches controlling electric light or power wiring.

Steel boxes designed to hold either a flush switch or a receptacle are made for this purpose. They are provided with holes into which the wire which is protected by flexible tubing may be carried. This requirement is necessary as the porcelains may be broken either in installing or afterward and, of course, in this condition would present a hazard unless encased in a fireproof enclosure such as the steel box demanded.

As there is always a liability of the face plate or enclosing box surrounding switches becoming alive from contact with the lighting wires no push button controlling bells or gas lighting circuits should ever be placed on the same wall plate with them, for under such conditions the lighting current could be carried on the bell wires. With gas lighting systems high tension sparks are sometimes used for the ignition of the gas and with the wires carrying this current on the same wall plate with lighting switches there would be a tendency for the high tension current to jump to the lighting circuit and cause grounds or short circuits.

e. Where possible, at all switch or fixture outlets, unless outlet boxes which will give proper support for fixtures are used, a seven-eighths inch block must be fastened between studs or floor timbers flush with the back of lathing to hold tubing, and to support switches or fixtures. When this cannot be done, wooden base blocks, not less than three-fourths inch in thickness, securely screwed to lathing, must be provided for switches, and also for fixtures which are not attached to gas pipes or conduit.

Figure 100 shows concealed wiring back of lathing leading to a double-pole flush switch. The board fastened between studdings must be cut out to admit the box of switch and the size of this box should be known when wires are put in. The board should not rest hard against the lathing, but leave a little space for plaster to work in behind the lath.

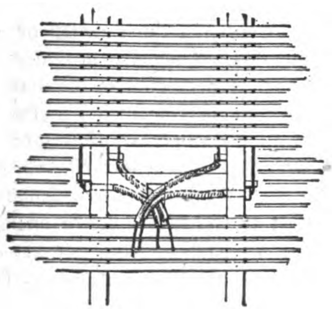


Figure 100.

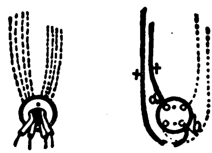


Figure 101.

Loom is put on all wires at outlets and must extend back to the nearest knob.

Figure 101 shows two methods of fastening snap switches by means of wooden blocks first fastened to the plaster. One block is cut out so as to bring all wires under the switch and entirely conceal them. The opening in block to admit wires and bushings should be oblong, so as to leave room on two sides for the screws with which the switch is to be fastened. On the other block the wires and bushing are brought through close to the outer edge of switch base. By careful workmanship a neat job can be done in this way. As most snap switches cross conductors, that is, connect points *a* and *b*, if from the nature of the case it becomes necessary to run any of the wires close together these two wires may be run that way, for they can never be of opposite polarity.

f. Sub-bases of non-combustible, non-absorptive, insulating material, which will separate the wires at least one-half inch from the surface wired over, must be installed under all snap switches used in exposed knob and cleat work. Sub-bases must also be used in moulding work, but they may be made of hardwood or they may be omitted if the switch is approved for mounting directly on the moulding.

25. Electric Heaters.

It is often desirable to connect in multiple with the heaters and between the heater and the switch controlling same an incandescent lamp of low candle power, as it shows at a glance whether or not the switch is open and tends to prevent its being left closed through oversight.

a. Must be protected by a cut-out and controlled by indicating switches. Switches must be double pole except when the device controlled does not require more than 660 watts of energy.

b. Must never be concealed, but must at all times be in plain sight.

Special permission may be given in writing by the Inspection Department having jurisdiction for departure from this rule.

c. Flexible conductors for smoothing irons and sad irons, and for all devices requiring over 250 watts must have an *approved* insulation and covering.

d. For portable heating devices the flexible conductors must be connected to an *approved* plug device, so arranged that the plug will pull out and open the circuit in case any abnormal strain is put on the flexible conductor. This device may be stationary, or it may be placed in the cord itself. The cable or cord must be attached to the heating apparatus in such manner that it will be protected from kinking, chafing or like injury at or near the point of connection.

e. Smoothing irons, sad irons, and other heating appliances that are intended to be applied to inflammable articles, such as clothing, must conform to the above rules so far as they apply. They must also be provided with an approved stand, on which they should be placed when not in use.

f. Stationary electric heating apparatus, such as radiators, ranges, plate warmers, etc., must be placed in a safe location, isolated from inflammable materials, and be treated as sources of heat.

Devices of this description will often require a suitable heat-resisting material placed between the device and its surroundings. Such protection may best be secured by installing two or more plates of tin or sheet steel with a one-inch air space between or by alternate layers of sheet steel and asbestos with a similar air space.

g. Must each be provided with name-plate, giving the maker's name and the normal capacity in volts and amperes.

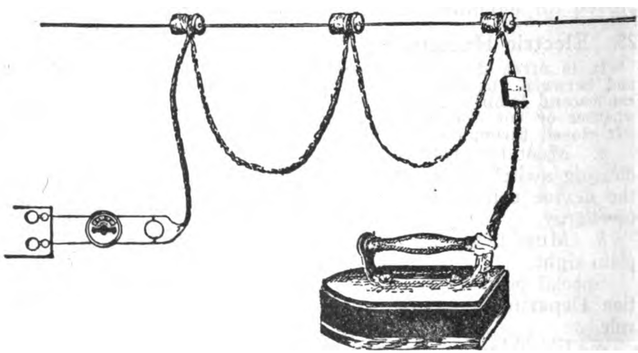


Figure 102.

In Figure 102 is given a diagram of a heater circuit with a 4 c. p. lamp in circuit. Where there are many irons in use, as in some tailoring establishments, it is advisable to run them all from one set of mains with a main switch convenient to exit door and have this switch opened whenever the irons are not in use. The individual switch at each iron should be located as near as possible to each iron. Cords feeding irons or cloth cutting machines are often installed as shown, insulators are strung on a tight wire and the cord tied to them. This allows considerable latitude in moving the iron.

LOW-POTENTIAL SYSTEMS.

550 Volts or Less.

Any circuit attached to any machine, or combination of machines, which develops a difference of potential between any two wires, of over ten volts and less than 550 volts, shall be considered as a low-potential circuit, and as coming under this class, unless an approved transforming device is used, which cuts the difference of potential down to ten volts or less. The primary circuit not to exceed a potential of 3,500 volts, unless the primary wires are installed in accordance with the requirements as given in No. 13, or are underground. For 550 volt motor equipments a margin of ten per cent above the 550 volt limit will be allowed at the generator or transformer.

26. Wires.

GENERAL RULES.

(See also Nos. 16, 17, 18 and 27. For construction rules see Nos. 49 to 57.)

a. Where entering cabinetes must be protected by approved bushings, which fit tightly the holes in the box and are well secured in place. The wires should completely fill the holes in the bushings so as to keep out the dust, tape being used to build up the wires if necessary. On concealed knob and tube work approved flexible tubing will be accepted in lieu of bushings, providing it shall extend from the last porcelain support into the cabinet.

b. Must not be laid in plaster, cement or similar finish, and must never be fastened with staples.

c. Must not be fished for any great distance, and only in places where the inspector can satisfy himself that the rules have been complied with.

Figure 103 illustrates a very common combination of "fish" and "moulding" work. Moulding is used to bring the wires from the floor to the ceiling and along the ceiling to a point opposite the outlet and parallel with the joists. From this point to the fixture the wires can then be readily fished.

The connection between the fish and moulding work should be made as shown at the right, where the moulding is cut

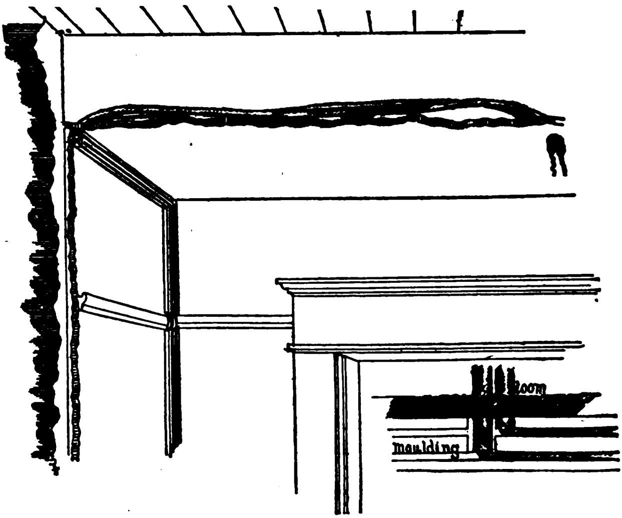


Figure 103.

out so as to admit the loom. It is better, even, to have the loom show to some extent than to have the wire come in contact with the plaster, as will very likely be the case if the loom is not fully brought through.

d. Twin wires must never be used, except in conduits, or where flexible conductors are necessary.

Flexible conductors are in general considered necessary only with pendant sockets, certain styles of adjustable brackets, portable lamps, motors and stage plugs, or heating apparatus.

e. Must where exposed to mechanical injury be suitably protected. When crossing floor timbers in cellars, or in rooms where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip, not less than one-half inch in thickness, and not less than three inches in width. Instead of the running boards, guard strips on each side of and close to the wires will be accepted. These strips to be not less than seven-eighths of an inch in thickness and at least as high as the insulators.

Protection on side walls must extend not less than five feet from the floor and must consist of substantial boxing,

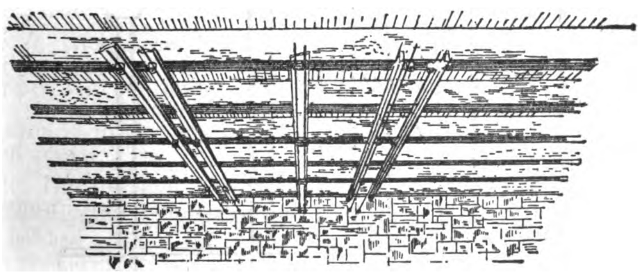


Figure 104.

retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes) or *approved* metal conduit or pipe of equivalent strength.

When metal conduit or pipe is used, the insulation of each wire must be reinforced by *approved* flexible tubing extending from the insulator next below the pipe to the one next above it, unless the conduit is installed according to No. 28 (Sections *c* and *f* excepted), and the wire is approved for conduit use. The two or more wires of a circuit *each* with its flexible tubing (when required), if carrying alternating current *must,* or if direct current, *may* be placed within the same pipe.

In damp places the wooden boxing may be preferable because of the precautions which would be necessary to secure proper insulation if the pipe were used. With this exception, however, iron piping is considered preferable to the wooden boxing, and its use is strongly urged. It is especially suitable for the protection of wires near belts, pulleys, etc.

Figure 104 illustrates the meaning of the rule in regard to wires run along low ceilings.

Figure 105 gives the dimensions necessary for the boxing surrounding wires on side walls. The figure also shows

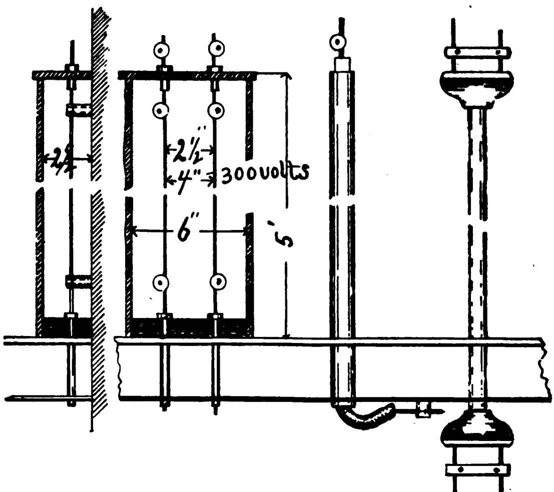


Figure 105.

the method of running wires in common iron pipe such as steam pipe. In this case the wires are each protected by an additional covering of flexible tubing. At the right of the figure is shown the more common method of using conduit for the protection of the wires. Approved conduit with outlet fittings at each end is securely fastened in place. Double braid, rubber covered wire, such as is required for conduit work must be used. The sections of the rule governing conduit work which do not apply in this case are: the wire may be pulled in before the mechanical work on the building is completed, and, it is not necessary to ground the conduit. This method of protecting wires is very satisfactory and is often used around belts and around machinery. Where the conditions are such as to require protection in a number of places it is often better to use single wires, each with a double braid, as this will do away with the necessity of splicing short lengths of double braid wire where passing through the short lengths of conduit.

f. When run in unfinished attics, will be considered as concealed, and when run in close proximity to water tanks or pipes, will be considered as exposed to moisture.

In unfinished attics, wires are considered as exposed to mechanical injury, and must not be run on knobs on upper edge of joists.

The question sometimes arises as to what is an "unfinished attic." In general an attic may be considered as unfinished when it is not provided with a floor and also with a permanent stairway leading to it. Attics are generally used for the storage of various household articles and where wires are run on tops of joists they are very liable to be injured. They should be run on the side of the joists and through bushings when running crosswise of the joists.

SPECIAL RULES.

For Open Work.

In dry places.

g. Must have an *approved* rubber, slow-burning weatherproof, or slow-burning insulation.

A slow-burning covering, that is, one that will not carry fire, is considered good enough where the wires are entirely on insulating supports. Its main object is to prevent the copper conductors from coming accidentally into contact with each other or anything else.

h. Must be rigidly supported on non-combustible, non-absorptive insulators, which will separate the wires from each other and from the surface wired over in accordance with the following table:

Voltage.	Distance from Surface	Distance between Wires.
0 to 300	½ inch	2½ inch
300 to 550	1 inch	4 inch

Rigid supporting requires under ordinary conditions, where wiring along flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports must be shortened. In buildings of mill construction, mains of not less than No. 8 B. & S. gage, where not liable to be disturbed, may be separated about six inches, and run from timber to timber, not breaking around, and may be supported at each timber only.

The neutral of a three-wire system may be placed in the center of a three-wire cleat where the difference of potential between the outside wires is not over 300 volts, provided the outside wires are separated two and one-half inches.

Must not be "dead-ended" at a rosette socket or receptacle unless the last support is within twelve inches of the same.

Rubber covered wire is ordinarily used for open work although slow-burning weatherproof wire or slow-burning wire may be used. The slow-burning weatherproof wire has an inner coating of weatherproof material of the same character as on outside weatherproof wire. Outside of the coating is placed a coating, fireproof in character, and similar to the covering on the so-called "underwriters" wire. The purpose of this covering is to provide an insulation which will protect the wires under ordinary circumstances. It is not suitable where moisture is present. The inner coating affords a fairly good insulating covering and the outer coating a protection against fire.

The slow-burning wire has a covering specially designed to withstand heat or fire and is only used in very hot places or where a number of wires are bunched. It is also used where gases or fumes are present which would have a tendency to destroy the rubber of the rubber-covered wire.

Figure 106 shows a number of methods of running wires in buildings of mill construction. At *a* the wires are carried

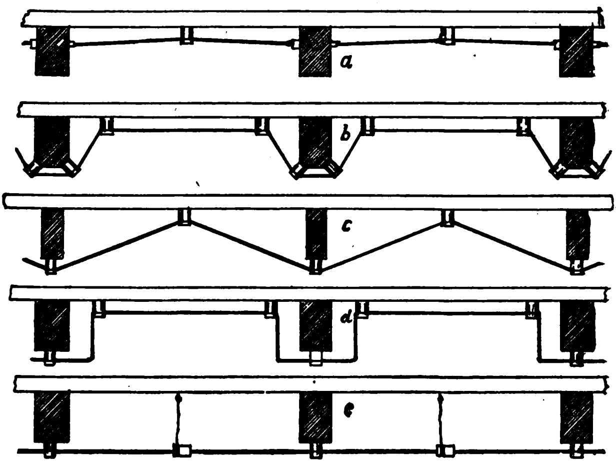


Figure 106.

through bushings through the beams and supported between beams on porcelain insulators. As beams in buildings of mill construction are generally quite thick, the installation of bushings is expensive and one of the other methods is generally used. The method shown at *b* is very frequently used. If the beams are not too thick the wires may be run as shown at *c*. If the wire is large and the ceiling is high so that wires are not liable to be disturbed they may be run as shown at *d*. With long spans an insulator may be placed on the wire and supported as shown at *e*.

In damp places, or buildings specially subject to moisture or to acid or other fumes liable to injure the wires or their insulation.

i. Must have an *approved* insulating covering.

For protection against water, rubber insulation must be used. For protection against corrosive vapors, either weatherproof or rubber insulation must be used.

j. Must be rigidly supported on non-combustible, non-absorptive insulators, which separate the wire at least one inch from the surface wired over, and must be kept apart at least two and one-half inches for voltages up to 300, and four inches for higher voltages.

Rigid supporting requires under ordinary conditions, where wiring over flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports must be shortened. In buildings of mill construction, mains of not less than No. 8 B. & S. gage, where not liable to be disturbed, may be separated about six inches, and run from timber to timber, not breaking around, and may be supported at each timber only.

In damp places wires are often run on the under side of an inverted trough as shown in Figure 107. The main point of usefulness of such a trough lies in the fact that it prevents drippings from wetting the wires and insulators. Condensation will, however, keep insulators and wires wet.

The trough to be useful should be put together with many screws or nails, the butting edges of the boards having been first painted with a waterproof paint, with which, when finished, the whole trough is also painted inside and out. If nails are used it will be found that cut iron nails are much less liable to corrosion than the ordinary wire nail. The trough should be made deep enough to protect the wires and should be hung as low as practicable so as to bring the wires into an even temperature. This construction will also avoid long drops or cords.

In connection with wiring in wet places, it is well to remember that a stranded wire is much more liable to corrosion than a solid wire, for, when exposed, the smaller wires of the strand provide a greater exposed surface than the equivalent solid wire. The space between the wires of a strand is very

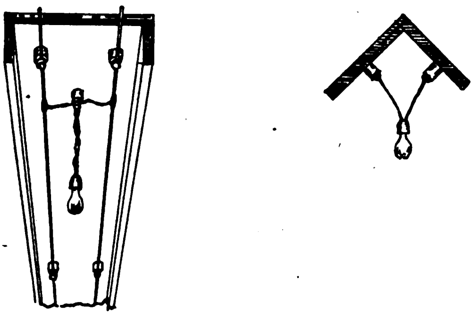


Figure 107.

liable to become full of water due to the capillary attraction of the small wires of the strand. With the trough method of construction the drops may be suspended from a split knob.

It is not practical to give exact rules covering electrical construction in all kinds of wet places or in locations exposed to acid fumes as the conditions vary greatly. Constant experiments are being carried on to determine the best class of construction for each particular class of service and the Inspection Department having jurisdiction should be consulted in each case before starting any work. It is found at the present time that in some locations it is necessary to change the wiring every year.

Each insulator when wet allows some current to leak over its surface and, therefore, the fewer we have the better the construction so long as there is no danger of the wires breaking. A form of construction which has given good service where others have failed consists of wires supported on petticoat insulators with the insulators some distance apart. It may be necessary to use a somewhat larger wire than ordinarily but the reduction in the losses from leakage and the trouble from grounds will more than repay the added expense. A modification of this construction consists in running wires on split knobs placed some distance apart with strain insulators at each end of the wire to take care of the strain.

If splices are necessary in wet places they should be made some distance away from the insulators, the insulation at the splice being always weaker than that of the unbroken wire. Care should always be taken that the insulation is not damaged by tying or by clamping under split knobs.

Weather proof sockets are required by the rule. Porcelain weatherproof sockets where exposed to changes in temperature will often crack and fall apart. In such places the moulded composition sockets are better. Brass shell sockets with the butt of the lamp and the entire socket taped and then compounded, while not in accordance with the rule, have proven very durable. In all cases whether the lamp is being used or not it should be left in the socket as it will tend to preserve the inner contacts of the socket.

When clusters are used the supporting stem should be left open at the bottom so that no accumulation of moisture can gather inside the stem. This construction will also allow a circulation of air which will tend to keep the wires inside the stem dry.

For Moulding Work (Wooden and Metal).

(See No. 29. For construction of Mouldings see No. 60.)

k. Must have an *approved* rubber insulating covering, and must be in continuous lengths from outlet to outlet, or from fitting to fitting, no joints or taps to be made in moulding. Where branch taps are necessary in moulding work *approved* fittings for this purpose must be used.

l. Must never be placed in either metal or wooden moulding in concealed or damp places, or where the difference of potential between any two wires in the same moulding is over 300 volts. *Metal* mouldings must not be used for circuits requiring more than 660 watts of energy.

m. Must for alternating current systems if in metal moulding have the two or more wires of a circuit installed in the same moulding.

It is suggested that this be done for direct current systems, also so that they may be changed to alternating systems at any time, induction troubles preventing such a change if the wires are in separate mouldings.

Figure 108 shows the dimensions of approved moulding.

Wires in moulding should always be approved rubber covered. Slow burning weatherproof wire, such as is allowed in

Figure 108.

some classes of open work, should never be used in moulding. For use in metal moulding single braid rubber covered wire is approved.

The rules covering moulding work in previous years allowed joints in the wire within the moulding. This is now forbidden for various reasons among which are the following: It is almost impossible to place a properly insulated joint in moulding as it is generally found necessary to cut away the tongue between the wires. There was a great tendency to leave joints unsoldered and in many cases untaped for, being covered, they could not be discovered without removing the capping. An overheated joint was almost sure to cause a

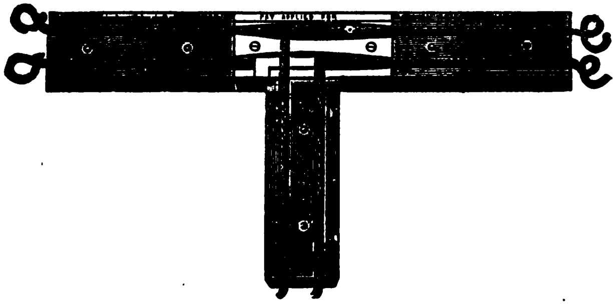


Figure 109.

fire. In making taps wires were often crossed under the capping.

The present construction demands the use of fittings for all branch taps, all receptacles and all drops. Fittings designed to be used for the purposes specified are shown in Figure 109.

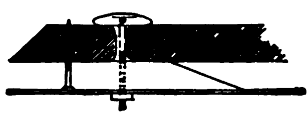


Figure 110.

Figure 110 shows how moulding should be fastened to tile ceiling. When toggle bolts are used, the nut should always be put on outside of capping (unless a very small one is used, or more than ordinary care is exercised). Many wiremen are careless and cut away the middle tongue too much, giving the nut a chance to work itself diagonally across it, so as to come in contact with both wires and, in time perhaps, cause short circuits. Although toggle bolts are mostly used, screws have

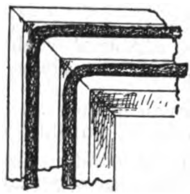


Figure 111.

been successfully used in tile. It is only necessary to first drill a hole of just the proper size for the screw to be used.

The proper way of making a square turn in moulding is

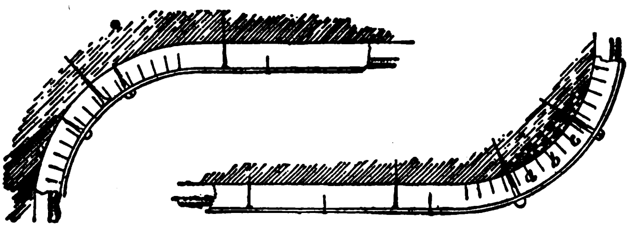


Figure 112.

shown in Figure 111. It will be noted that the sharp ends of the moulding are cut away at the turns.

Figure 112 shows methods of running around corners. The saw cuts, a, b, c, etc., should be made with a fine saw and for short bends require to be close together. Bending is facilitated by wetting the moulding, and if, before the moulding is put in place, the saw cuts are filled with glue, it will greatly add to the durability of the job. Screws or nails used in fastening the capping should pass through the moulding into the wall to get a firm hold.

For Conduit Work.

n. Must have an *approved* rubber insulating covering, and must within the conduit tubing be without splices or taps.

o. Must not be drawn in until all mechanical work on the building has been, as far as possible, completed.

Conductors in vertical conduit risers must be supported within the conduit system in accordance with the following table:—

No. 14 to 0 every 100 feet.
No. 00 to 0000 every 80 feet.
0000 to 350,000 C. M. every 60 feet.
350,000 C. M. to 500,000 C. M. every 50 feet.
500,000 C. M. to 750,000 C. M. every 40 feet.
750,000 C. M. every 35 feet.

The following methods of supporting cables are recommended:—

1. A turn of 90 degrees in the conduit system will constitute a satisfactory support.
2. Junction boxes may be inserted in the conduit system at the required intervals, in which insulating supports of *approved* type must be installed and secured in a satisfactory manner so as to withstand the weight of the conductors attached thereto, the boxes to be provided with proper covers.
3. Cables may be supported in *approved* junction boxes on two or more insulating supports so placed that the conductors will be deflected at an angle of not less than 90 degrees, and carried a distance of not less than twice the diameter of the cable from its vertical position. Cables so suspended may be additionally secured to these insulators by tie wires.

Other methods, if used, must be aprpoved by the Inspection Departments having jurisdiction.

p. Must, for alternating systems, have the two or more wires of a circuit drawn in the same conduit.

It is suggested that this be done for direct current systems also so that they may be changed to alternating systems at any time, induction troubles preventing such a change if the wires are in separate conduits.

The same conduit must not contain more than four two-wire, or three three-wire circuits of the same system, except by special permission of the Inspection Department having jurisdiction, and must never contain circuits of different systems.

Rubber covered wire only may be used in conduit. For conduit with a lining of insulated material single braid wire may be used. For unlined conduit the wire must have two braids or one tape and a braid. The two braids are preferable for twin or duplex wires for the reason that where the outer braid of the duplex wire is removed as at switch and fixture outlets tape is apt to unwind and leave the wire with a rubber covering only. With the duplex wire having braids on each wire the single wires will still be protected by braids. Rule *o* is required to insure the protection of the wiring from mechanics working on the building. It also insures that there will be no runs installed in which the wire cannot be at any time inserted. Where the wire is pulled into the conduits before the mechanical work is entirely finished there is a temptation to open long conduit runs at the middle and pull the wires both ways. Obviously, it will be a difficult matter to replace such runs should they burn out.

Figure 113 shows different methods employed to fasten wires in vertical runs in conduits. In the upper left-hand figure insulators are used, reinforced by metal straps so arranged that they will prevent the insulators from being pulled off sideways. The method shown in the lower figure is sometimes used with cables so heavy that the rubber insulation will not stand the strain of supporting them. The figure shows a clamp made of copper so that it can be soldered to the bare wires of the cable. This clamp is mounted on slate so as to furnish the insulation necessary for the cable.

If a single wire carrying alternating currents of electricity were run in iron pipe there would be a very large drop in

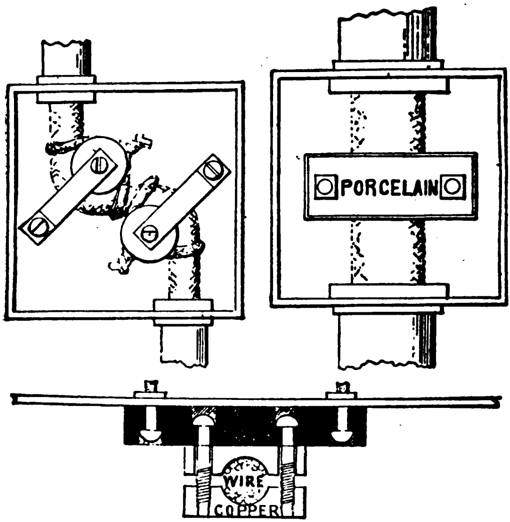


Figure 113.

voltage. This drop is due to the fact that all currents while changing in strength generate a counter E. M. F. in their surroundings. This is particularly strong when the wires are surrounded by, or very close to, iron. If both wires are run in the same pipe the current in one wire neutralizes that of the other and there is no trouble.

Figure 113A and the tabulation given below are designed to assist in laying out conduit runs where turns are to be made or where there are obstructions as in mill-constructed buildings. In the column at the left are given various radii of bends. In column 1 is shown the saving in length of conduit effected by making single bends of different radius over what would be required to make square turns.

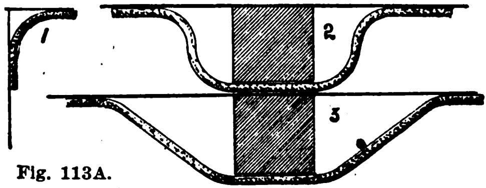


Fig. 113A.

To find the actual length of conduit required, measure the run as though it were made square and subtract the length in inches set opposite the corresponding radius of bend. If the bend is made a true circle the radius will be equal to the distance from beginning of bend to where the conduit strikes the ceiling.

Where it is necessary to run around a beam as shown in column 2 and the same radius of bend is used there will be four bends and the saving will be four times as great as for the single bend, but it must be borne in mind that a four-inch radius, for instance, cannot be used unless the beam is at least eight inches high.

In many cases the run around a beam is made about as indicated in column 3. The saving effected by this manner of bending is approximately given in column 3.

Radii of bends, inches	1 Saving in conduit, inches	2 Saving in conduit, inches	Height of beam, inches	3 Saving in conduit, inches
3	1 5/16	5 1/4	1	1/2
4	1 3/4	7	2	1
5	2 1/8	8 1/2	3	1 1/2
6	2 5/8	10 1/2	4	2
7	3	12	5	2 1/2
8	3 7/16	13 3/4	6	3
9	3 7/8	15 1/2	7	3 1/2
10	4 5/16	17 1/4	8	4
11	4 3/4	19	9	4 1/2
12	5 3/16	20 3/4	10	5
13	5 5/8	22 1/2	11	5 1/2
14	6 1/16	24 1/4	12	6

The following tables show the number of wires of various sizes which are allowed in conduit. These tables appear in the 1915 edition of the National Electrical Code. In this same edition the rules governing the construction of rubber-covered wire were changed to allow all wires up to and including No. 8 B. & S. gauge to have a single-braid covering. This change in the rule was not taken into account in compiling the tables given in the National Electrical Code and due to the fact that the single-braid covering is somewhat smaller than the previously required double-braid covering, many cities are permitting more wires in a conduit than those shown in the tables, which appear in the National Electric Code. Tables have, therefore, been added showing combination using single-braid wires in conduit.

3 Conductor Convertible System

Size of conductors		Size Conduit, in.
2-conductor Size B. & S.	1-conductor Size B. & S.	Electrical trade size
14	10	¾
12	8	¾
10	6	1
8	4	1
6	2	1¼
5	1	1¼
4	0	1½
3	00	1½
2	000	1½
1	0000	2
0	250000	2
00	350000	2½
000	400000	2½
0000	550000	3
250000	600000	3
300000	800000	3
400000	1000000	3½
500000	1250000	4
600000	1500000	4
700000	1750000	4½
800000	2000000	4½

Size of Conduits for the Installation of Wires and Cables

	One conductor in a conduit	Two conductors in a conduit	Three conductors in a conduit	Four conductors in a conduit
Size B. & S.	Electrical trade size	Electrical trade size	Electrical trade size	Electrical trade size
*14	½	½	½	¾
*12	½	¾	¾	¾
*10	½	¾	¾	1
* 8	½	1	1	1
6	½	1	1¼	1¼
5	¾	1¼	1¼	1¼
4	¾	1¼	1¼	1½
3	¾	1¼	1¼	1½
2	¾	1¼	1½	1½
1	¾	1½	1½	2
0	1	1½	2	2
00	1	2	2	2½
000	1	2	2	2½
0000	1¼	2	2½	2½
CM				
200000	1¼	2	2½	2½
250000	1¼	2½	2½	3
300000	1¼	2½	2½	3
400000	1¼	3	3	3½
500000	1½	3	3	3½
600000	1½	3	3½	
700000	2	3½	3½	
800000	2	3½	4	
900000	2	3½	4	
1000000	2	4	4	
1250000	2½	4½	4½	
1500000	2½	4½	5	
1750000	3	5	5	
2000000	3	5	6	

*Single Conductor, Single Braid, Solid Wires Only

(This table is not to be used for double braid wires, twin or duplex wires or stranded wires.)

14	½	½	½	½
12	½	½	½	¾
10	½	¾	¾	1
8	½	¾	¾	1

Size of Conduit for the Installation of Wires.

Twin Conductor.

	One conductor in a conduit	Two conductors in a conduit	Three conductors in a conduit	Four conductors in a conduit
Size B. & S.	Electrical trade size	Electrical trade size	Electrical trade size	Electrical trade size
14	½	¾	1	1
12	½	¾	1	1¼
10	¾	1	1¼	1¼

Combinations Where Double Braid, Twin or Duplex Wires Are Used

No. of Wires	Size conduit, in. Electrical trade size
*5 No. 14 R. C. solid	¾
*10 No. 14 R. C. solid	1

Where special permission has been given in accordance with No. 26, p, the following table to apply:

18 No. 14 R. C. solid	1¼
24 No. 14 R. C. solid	1½
40 No. 14 R. C. solid	2
74 No. 14 R. C. solid	2½
90 No. 14 R. C. solid	3

***Combinations Where Single Conductor, Single Braid, Solid Wires Are Used.**

(This table is not to be used for double braid wires, twin or duplex wires.)

No. of Wires	Size conduit, in. Electrical trade size
7 No. 14 R. C. solid	¾
12 No. 14 R. C. solid	1

For Concealed "Knob and Tube" Work.

q. Must have an *approved* rubber insulating covering.

r. Must be rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least one inch from the surface wired over. Should preferably be run singly on separate timbers, or studding, and must be kept at least five inches apart.

Must be separated from contact with the walls, floor timbers and partitions through which they may pass by non-combustible, non-absorptive, insulating tubes, such as glass or porcelain. Wires passing through cross timbers in plastered partitions must be protected by an additional tube extending at least four inches above the timber.

Rigid supporting requires, under ordinary conditions, where wiring along flat surface, supports at least every four and one-half feet. If the wires are liable to be disturbed the distance between supports must be shortened.

At distributing centers, outlets or switches where space is limited and the five-inch separation cannot be maintained, each wire must be separately encased in a continuous length of approved flexible tubing.

In concealed knob and tube work the wires are supported on split knobs on the sides of joists and floor studdings and by porcelain tubes where passing through timbers. All wires must be separated one inch from the surface wired over so that the ordinary porcelain cleats must never be used for this work.

Concealed knob and tube work was formerly used for all concealed work in frame buildings but many cities are now prohibiting its use for the following reasons:

There is a great liability of disturbing the wires after they have been installed.

No matter how careful the wireman may be in placing the wires other mechanics on the building are apt to place wood beams or other obstructions in contact with the wires after the wireman has left the work as completed.

The porcelain bushings are very liable to be jarred out of the joists through hammering in the laying of the floor or in the other work necessary to the completion of the building.

Pipes or other metal work may be placed in contact with the wires either in completing the building or in changes required after the building is completed.

If a fire should for any reason start on the wires the rub

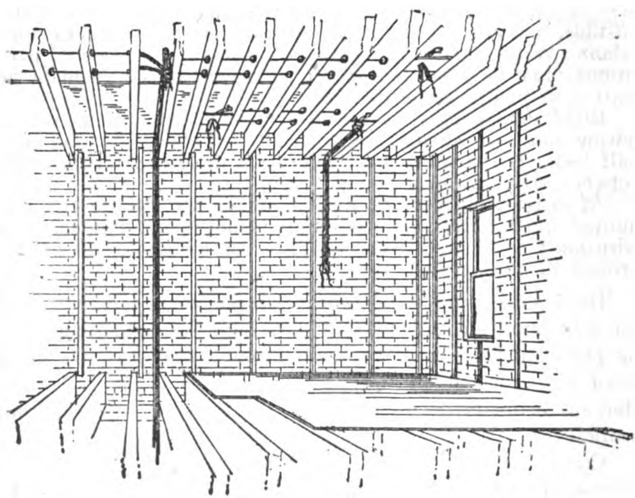


Figure 114.

ber covering is very inflammable and might conduct the fire to the combustible woodwork surrounding the wires.

Figure 71 shows the manner in which bushings are placed through the joists. The method shown in the upper part of the figure is preferable. In attics the wires must not be run on the upper edges of joists as in this position they are considered as exposed to mechanical injury (see Rule No. 26 f).

s. When in a concealed knob and tube system, it is impracticable to place the whole of a circuit on non-combustible supports of glass or porcelain, that portion of the circuit which cannot be so supported must be installed with *approved* metal conduit, or *approved* armored cable, except that if the difference of potential between the wires is not over 300 volts, and if the wires are not exposed to moisture, they may be fished if separately encased in *approved* flexible tubing, extending in continuous lengths from porcelain support to porcelain support, from porcelain support to outlet, or from outlet to outlet.

An illustration of wiring on the "loop" system is shown in Figure 114. This system makes it unnecessary to have any concealed joints or splices. The amount of wire required is somewhat in excess of that required for tap systems, but this is often balanced by a saving in labor. Sometimes, however, the labor is also in excess of that required for tap systems. The main advantage of the system is that all joints and splices are always accessible. The figure also shows mixed "knob and tube" work and "conduit" work. Along the walls behind the furring strips there is seldom sufficient space to admit of knob and tube work and conduit must be used.

Figure 115 is drawn to illustrate "fish work." Fish work is used in finished buildings, mostly, and is often very tedious and expensive. Hours are sometimes spent before wires can be brought through and often the effort is an entire failure. In combination work, as shown in Figure 103, there is usually little trouble, as there is the whole span between joists to run wires in. An effort to fish at right angles to the joists (when there are strips under joists) is more difficult, but often successful if the distance is not too great.

When there are two men the usual method of fishing is: One man takes a wire sufficiently long to reach from one opening to the other, and, after bending a small hook on one end in such a way that it will not catch easily on obstructions, pushes this end into one opening and, by twisting and working backward and forward, gradually forces it toward the other opening. At this opening his helper is stationed with a short wire, also provided with a hook, with which he must seek to catch the other wire when it comes near his opening. When the two wires come in contact, the larger one is drawn out and the conducting wires (encased in approved flexible tubing) are fastened to it and drawn through. The tubing should always be put on the wires before drawing in. If it is put on

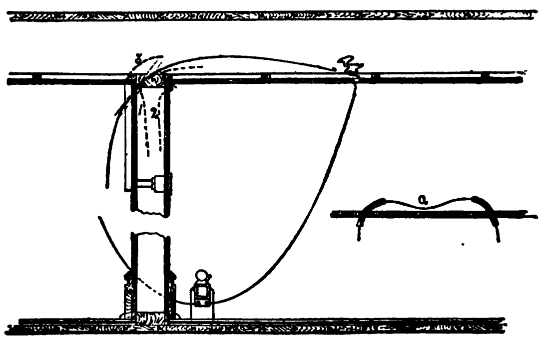


Figure 115.

later there is much temptation to leave it as indicated at the right of the figure at *a*. This trick is quite common, but is very easily detected by inspectors; the wire at either end can easily be pushed in without pushing out at the other, as it would if the tubing were continuous. If the tubing has been taped to the wires this will be impossible, but either one of the tubings can still be moved without moving the other, which would be impossible in a job properly done. The tubing must consist of one piece, and there must be only one wire in each tubing.

If one man is alone on a fish job, a handful of small wire is pushed into one opening in a manner which will allow it to spread out considerably. When the fish wire from the other opening comes in contact with it, it will indicate it by moving this wire, which can be seen by that left hanging out. A small fish wire is then used to draw out the long one. If the two openings are in different rooms and not visible, one from the other, a bell and battery can be used, as shown in the drawing, if there are no wire lath.

When wires are to be entirely concealed it is nearly always necessary to find a way through headers, timbers, etc.; this can hardly be done without cutting holes in plaster. A method doing as little damage as any is shown at the top in Figure 115. A hole is bored through the 2 × 4, which will allow the wire, when job is finished, to continue downward as shown by dotted lines, 1 and 2. Such turns are seldom ever used with electric light wires on account of their size; they are more practicable with bell or telephone wires.

Where it is desired to keep wires from showing in a parlor, for instance, they can be fished from an adjoining room, as indicated by dotted line 3, where the wires are run down partition in moulding in closet and then through to switch, which is in the same room with the lights. Before undertaking a job of fish work it is well to look the whole building over carefully. There are often false walls along chimneys, especially at both sides of mantels, in which wires can be easily run from basement to attic.

Often it may be necessary to remove baseboards in order to find room for wires. When removing such boards never attempt to drive nails out, always break them off; if driven out they will usually split off parts of the board.

Soft wood floors can easily be taken up when necessary.

Use a broad thin chisel and cut away the tongue on each side of the board to be taken up; the board can then be readily taken up. With double floors or with tightly laid hardwood floors, it is better to cut pockets in ceiling below.

t. When using either conduit or armored cable in mixed concealed knob and tube work, the requirements for conduit work or armored cable work must be complied with as the case may be.

u. Must at all outlets, except where conduit is used, be protected by *approved* flexible tubing, extending in continuous lengths from the last porcelain support to at least one inch beyond the outlet. In the case of combination fixtures the tubes must extend at least flush with outer end of gas cap.

When the surface at any outlet is broken, it must be repaired so as to leave no holes or open spaces at such outlet.

It is suggested that *approved* outlet boxes or plates be installed at all outlets in concealed "knob and tube" work, the wires to be protected by *approved* flexible tubing, extending in continuous lengths from the last porcelain support into the box.

An installation of mixed concealed knob and tube work is shown in Figure 114. Where it is necessary to use conduit, as is often the case on brick walls, the conduit should extend from outlet to outlet (from the side bracket to the ceiling outlet in Figure 114). If there is no available outlet on the circuit a junction box should be placed at the ceiling line but in all cases this junction box should be accessible. The conduit should never end in the concealed space under the floor for, should the wire in the conduit burn out it would be impossible to replace it. The proper method for cases of this kind is shown in Figure 118.

Figure 126 shows in detail the method of bringing wires out at a fixture outlet. The flexible tubing being carried flush with the lower end of the gas cap the wires will be protected when the fixture is put in place. It will be noted that the rule requires the flexible tubing to be continuous. The reason for this is quite evident for, were short pieces used, the wire might protrude at the point of connection and come in contact with the gas pipe. Figure 126 also shows the proper method of fastening a wire where it comes through a bushing at an outlet. In all cases the wires should be fastened under a knob after passing through the bushing so that they will not slip back and come in contact with the woodwork.

There are probably more electrical fires started at fixture outlets than at any other point on the system and it is very essential that should a fire start at this point it be afforded no means for spreading. It will be noticed that when a hole is made in a ceiling in a frame building a strong draft is nearly always evident and for this reason care should always be taken to see that all openings into the concealed space back of the plaster are entirely closed.

For Fixture Work.

v. Must be not smaller than No. 18 B. & S. gage, and must have an approved rubber insulating covering (see No. 55).

In wiring certain designs of show-case fixtures, ceiling bulls-eyes and similar appliances in which the wiring is exposed to temperatures in excess of 120 degrees Fahrenheit (49 degrees Centigrade), from the heat of the lamps, *approved* slow-burning wire may be used. All such forms of fixtures must be submitted for examination, test and approval before being introduced for use.

w. Supply conductors, and especially the splices to fixture wires, must be kept clear of the grounded part of gas pipes, and, where shell or outlet boxes are used, they must be made sufficiently large to allow the fulfillment of this requirement.

x. Must, when fixtures are wired outside, be so secured as not to be cut or abraded by the pressure of the fastenings or motion of the fixture.

y. Wires of different systems must never be contained or attached to the same fixture, and under no circumstances must there be a difference of potential of more than 300 volts between wires contained in or attached to the same fixtures.

27. Armored Cables.

(See also No. 26 s. For construction of Armored Cables see No. 57.)

a. Must be continuous from outlet to outlet or to junction boxes, and the armor of the cable must properly enter and be secured to all fittings, and the entire system must be mechanically secured in position.

In case of service connections and main runs, this involves running such armored cable continuously into a main cut-out cabinet or gutter surrounding the panel board, as the case may be.

b. Must be equipped at every outlet with an *approved* outlet box or plate, as required in conduit work.

Outlet plates must not be used where it is practicable to install outlet boxes.

The outlet box or plate shall be so installed that it will be flush with the finished surface, and if this surface is broken it shall be repaired so that it will not show any gaps or open spaces around the edge of the outlet box or plate.

In buildings already constructed where the conditions are such that neither outlet box nor plate can be installed, these appliances may be omitted by special permission of the Inspection Department having jurisdiction, provided the armored cable is firmly and rigidly secured in place.

c. Must have the metal armor of cables permanently and effectually grounded to water piping, gas piping or suitable ground plate, provided that when connections are made to gas piping, they must be on the street side of the meter. If the armored cable system consists of several separate sections, the sections must be bonded to each other, and the system grounded, or each section may be separately grounded, as required above.

The armor of cables and gas pipes must be securely fastened in outlet boxes, junction boxes and cabinets, so as to secure good electrical connection.

If armor of cables and metal of couplings, outlet boxes, junction boxes, cabinets or fittings having protective coating of non-conducting material, such as enamel are used, such coating must be thoroughly removed from threads of both couplings and the armor of cables, and from surfaces of the boxes, cabinets and fittings where the armor of cables or ground clamp is secured in or-

Where armored cable is run through holes bored through joists or is laid in notches cut in same it should be so placed that nails used in fastening down floors, especially hardwood floors, will not strike the metal armor, as under these conditions it is possible for a nail to be driven through the armor and make contact with the wires. While short circuits and grounds due to the cause just mentioned are not very common the expense of taking up floors may be considerable.

Short bends should be avoided in the use of all armored cables. When the bend is short there is some strain which may cause the wire to come into contact with the metal strip of the armor. This will not produce bad effects at once but may do so after a long time. It is well also to test all coils of armored cable for continuity as well as for grounding or short circuits before installing.

28. Interior Conduits.

(See also No. 26 n to p. For construction of Conduit see No. 58, and for construction of Outlet, Junction and Flush Switch Boxes see No. 59.)

The object of a tube or conduit is to facilitate the insertion or extraction of the conductors and to protect them from mechanical injury. Tubes or conduits are to be considered merely as raceways, and are not to be relied upon for insulation between wire and wire or between the wire and the ground.

The installation of wires in conduit not only affords the wires protection from mechanical injury, but also reduces the liability of a short circuit or ground on the wires producing an arc, which would set fire to the surrounding material; the conduit being generally of sufficient thickness to blow a fuse before the arc can burn through the metal of the pipe. For this reason the wires should be entirely encased in metal throughout, both in the conduit and at all outlets. Another advantage derived from the use of iron conduit is the facility with which wires can be extracted and replaced in case a fault develops on any of them. The saving which this may mean in cases where the installation of new wires would necessitate the destruction of costly decorations can readily be seen.

It must be remembered that the arc or burn produced by a short circuit or ground is proportional to the size of the fuse protecting the circuit. If a large fuse, say 30 amperes, is used to protect a branch circuit and a ground or short occurs on this circuit, the wire may become fused to the pipe so that it cannot easily be pulled out. This is one reason why fuses should be as small as practicable. More than six amperes is seldom used on branch circuits, so that no larger fuse than this should ordinarily be used. The installation of wires in iron conduit also reduces the liability of lightning discharges entering a building as the pipe surrounding the wires offers great resistance to the passage of these sudden currents.

Conduit is classed under two general heads, lined and unlined. In both classes of conduit the same thickness of metal is required. Lined conduit is used but little at the present time.

a. No conduit tube having an internal diameter of less than five-eighths of an inch shall be used. Measurements to be taken inside of metal conduits.

This rule favors lined conduit insomuch that it requires the same pipe for lined and unlined, and allows a lined conduit of less than five-eighths of an inch in diameter.

Nominal one-half inch conduit has an internal diameter of five-eighths of an inch.

b. Must be continuous from outlet to outlet or to junction boxes, and the conduit must properly enter, and be secured to all fittings and the entire system must be mechanically secured in position.

In case of service connections and main runs, this involves running each conduit continuously into a main cut-out cabinet or gutter surrounding the panel board, as the case may be.

When conduit is used every run of pipe must end in accessible outlet boxes. This box may be a cut-out center, switch outlet, fixture outlet or a junction box. If a mixed form of wiring is used, where part of a circuit is run in conduit and

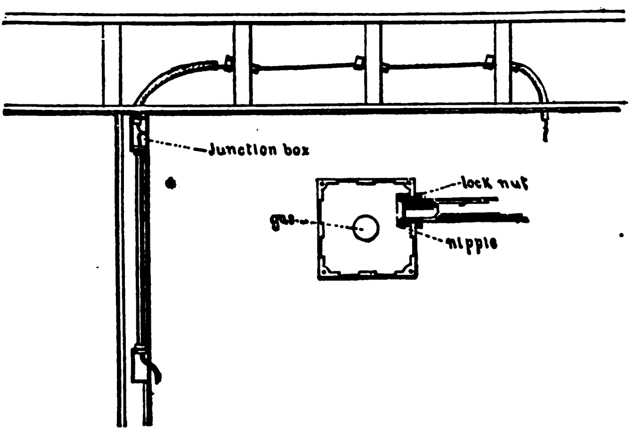


Figure 118.

the balance with some other form of construction, such as concealed knob and tube work, for instance, the conduit must in all cases enter the box and be firmly attached to it, as shown in Figure 118. Cases are sometimes found where the conduit is brought just to the box, but does not enter it, the wires being extended through holes into the box. This method of wiring, is obviously wrong, as a wireman is apt to find if he ever has oocassion to replace wires in such a system. The same holds true of cut-out centers. Here also every run of conduit must enter the box. The conduit should not simply be brought to the sides or the back of the cut-out center and the wires then carried to the cut-outs in flexible tubing, but every conduit should enter clear into the box so that when

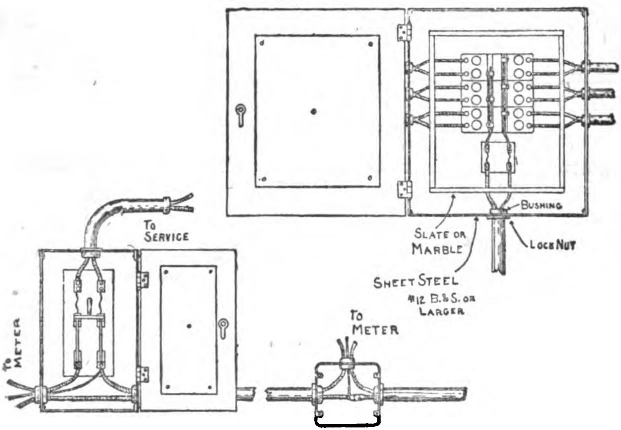


Figure 119.

the work is completed there will be no exposed wiring. In the case of main runs the conduit should enter the boxes and never be broken between the outlets. Sometimes it is necessary to install meters on the mains and the conduit is ended and the wires carried to the meters and then either extended in conduit or carried into the cut-out center. This construction should be avoided. If a meter is to be installed near a cut-out center, the main conduit should be carried into the box and the necessary meter loops then brought out. In this way the quantity of wire outside of conduits is reduced to a minimum. If a meter is to be installed in some location along the mains other than at the cut-out center or service switch, a junction box should be provided and the meter loops brought out from that. This is shown in Figure 119, which also shows a cut-out box as used with conduit systems.

c. Must be first installed as a complete conduit system, without the conductors.

As fast as the conduit is installed, the ends of the pipes should be closed, using paper or corks. This lessens the liability of plaster or other substances entering the pipes and causing trouble when the wires are to be pulled in. The conductors should not be pulled in until all the mechanical work on the building is, as far as possible, finished. When a conduit system is ready for the wires, the 'pulling in" may be done in various ways. For short runs, all that is necessary is to shove the wires in at one opening until they come out at the other. If a run is too long to be inserted in this way, what is known as a "fish wire" can be used. The ordinary fish wire is a flat band of steel about 5/32 inch wide and 1/32 inch thick. This wire can be forced through any ordinary length of pipe. Ordinary round steel wire of about No. 12 or 14 B. & S. gage can also be used, although this is not as good as the fish wire above described.

The end of the wire is first bent back so as to form a very small hook or eye; this will enable it to slide easily over obstructions in the pipe and also make it possible should it stick somewhere to engage it with another fish wire provided with a suitable hook and entered from the other end of the pipe. This is very often necessary in runs having many bends. The fish wire, having been pushed through the pipe, is now fastened to the copper wire by means of a strong hook and the copper wire pulled into the pipe.

In pulling in the large size cables, it is often found advantageous to pull on the fish wire and at the same time push on the end of the cable entering the pipes. It is also well to remember that it is easier to pull down than to pull up, as, when pulling down, the weight of the cable assists. The use of soapstone facilitates the drawing in of the wires. The wire may either be covered with the powdered soapstone or the soapstone may be blown into the pipes. An elbow partly filled with soapstone is often found convenient for blowing the soapstone into the pipe, always blowing from the highest point.

Graphite or axle grease should never be used for this purpose, as the graphite is a conductor and the axle grease will rot the rubber insulating covering of the wire.

d. Must be equipped at every outlet with an *approved* outlet box or plate. At exposed ends of conduit (but not at fixture outlets) where wires pass from the conduit system without splice, joint or tap, an approved fitting having separately bushed holes for each conductor is considered the equivalent of a box.

Outlet plates must not be used where it is practicable to install outlet boxes.

The outlet box or plate must be so installed that it will be flush with the finished surface, and if this surface is broken it shall be repaired so that it will not show any gaps or open spaces around the edge of the outlet box or plate.

In buildings already constructed where the conditions are such that neither outlet box nor plate can be installed, these appliances may be omitted by special permission of the Inspection Department having jurisdiction, providing the conduit ends are bushed and secured.

It is suggested that outlet boxes and fittings having conductive coatings be used in order to secure better electrical contact at all points throughout the conduit system.

The object of an outlet box is to hold the conduits firmly in place, to connect the various runs of conduit so that they form a continuous electrical path to the ground, and to afford a fireproof enclosure for the joints, switches, etc. Outlet boxes are made in various designs to meet the requirements of the work on which they are to be used.

Where it is impossible to use an outlet box, an outlet plate can be used. These plates are fitted with clamps so that they hold the ends of the conduits firmly in position and make the metal of the system continuous. They do not afford a fireproof enclosure for the joints and for that reason should never be used when it is practicable to use an outlet box. If the conditions are such that neither an outlet box nor plate can be used, special permission can be obtained from the Inspection Department having jurisdiction to omit them. In this case the conduits should be bushed at the ends and the pipes should be bonded together.

This rule requires that an outlet box or plate be used at *every* end of a run of conduit. For the ordinary switch, fixture, and like outlet suitable boxes are available. At exposed ends of conduit special fittings are on the market and

Figure 120.

should be used. These fittings are especially desirable for the following reasons: They separate the wires where they leave the conduit and thus tend to destroy any arc which might result at the weakest point of the conduit system; the point where the wires leave the pipe. They also provide an insulated bushing at that point at which the strain on the insulation of the wires is generally the greatest. They also serve to separate the wires in a proper manner, when they leave the fitting. Fittings designed for this purpose are shown in Figure 120.

e. Metal conduits where they enter junction boxes, and at all other outlets, etc., must be provided with *approved* bushings or fastening plates fitted so as to protect wire from abrasion, except when such protection is obtained by the use of approved nipples, properly fitted in boxes or devices.

When a piece of conduit is cut with a pipe cutter, a sharp edge is left on the inside. This edge, if left on, would soon cut into the insulation of the wires. It should be removed by means of a pipe reamer. The bushing can now be screwed on as shown in Figure 118, a locknut having first been screwed onto the pipe. The locknut and bushing are then screwed up so that they are tight and form a good connection.

f. Must have the metal of the conduit permamently and effectually grounded to water piping, gas piping or suitable ground plate, provided that when connections are made to gas piping, they must be on the street side of the meter. If the conduit system consists of several separate sections, the sections must be bonded to each other, and the system grounded, or each section may be separately grounded, as required above. Where short sections of conduit (or pipe of equivalent strength) is used for the protection of exposed wiring on side walls, and such conduit or pipe and wiring is installed as required by No. 26 *e*, the conduit or pipe need not be grounded.

Conduits and gas pipes must be securely fastened in outlet boxes, junction boxes and cabinets, so as to secure good electrical connections.

If conduit, couplings, outlet boxes, junction boxes, cabinets or fittings, having protective coating of non-conducting material such as enamel are used, such coating must be thoroughly removed from threads of both couplings and conduit, and such surfaces of boxes, cabinets and fittings where the conduit or ground clamp is secured in order to obtain the requisite good connection. Grounded pipes should be cleaned of rust, scale, etc., at place of attachment of ground clamp.

Connections to grounded pipes and to conduit must be exposed to view or readily accessible, and must be made by means of approved ground clamps to which the ground wires must be soldered.

Ground wires must be of copper, at least No. 10 B. & S. gage (where largest wire contained in conduit is not greater than No. o B. & S. gage), and need not be greater than No. 4 B. & S. gage (where largest wire contained in conduit is greater than No. o B. & S. gage). They shall be protected from mechanical injury.

That the metal in a conduit system should be permanently and effectually grounded is plainly evident when the hazards which are present with ungrounded or poorly grounded conduit are recalled. Until recently very little attention has been given to the matter of properly grounding conduits, but with the increased use the necessity of so doing has become very apparent. If a bare wire on one side of a system comes in contact electrically with the iron pipe and if there is a ground on the other side of the system (and there always is with 3-wire systems) the conduit becomes a conductor. If the conduit system is so installed that every piece is in good electrical connection and the entire system effectually grounded no harm will be done except the blowing of a fuse.

Conduit is installed in all kinds of locations. It may be in contact with a gas pipe, lead pipe, or run in a damp floor, or it may be run exposed where a person could easily come in contact with it. The effects that might result from a conduit so run should the conduit become alive are readily seen. Suppose that in the first case the conduit crosses the gas pipe at right angles, the area of contact would be very small and the effect of the current in a livened conduit crossing this poor contact would result in burning a hole in the gas pipe and igniting the escaping gas. Again, suppose the conduit run in a damp floor should become alive; the damp woodwork, being a conductor, would soon char and the charred part would then readily ignite.

With a system which is grounded, an exposed piece of conduit will usually only be alive for a very short time during the blowing of the fuse. Even if it remains permanently alive, current will not flow from it to the surrounding material, but will take the easiest path to ground, which is along the conduit. On the ordinary branch circuits, the vari-our runs of conduit are bonded together through the outlet boxes and, in connecting the conduits to these boxes, care must be taken that they make good contact. In order to do this, the conduit should enter at right angles to the box and the enamel should be scraped away from the box so that the locknut and bushing make good electrical connection. The same thing should be done where the conduit enters the cut-out box. The metal of the cut-out box will bond together the various branch conduits and the main conduit. The main conduit should now be connected to some good ground, such as a water pipe or metal work of the building. Never carry the ground wire to a gas pipe unless on the street side of a meter. The various branch conduits should also be grounded wherever possible, at and on metal beams over which they cross and at every gas outlet. The reason of grounding the gas pipe thoroughly at the gas outlets is to be sure of a good ground. The gas pipe is necessarily in contact with the outlet box at this point and any poor contact which might cause arcing must be avoided.

The rule specifies a No. 10 wire for grounding conduit where the wire in the conduit system is not larger than No. 0. According to the table of carrying capacities a No. 0 wire will carry 127 amperes and while the No. 10 ground wire may be called upon to carry current sufficient to blow a fuse of this size, the current will last for but a short time and the ground wire will not have time to become dangerously hot.

Special devices for attaching the ground wire to both the conduit and to grounded pipes are on the market and should always be used. Figure 121 shows two forms of ground clamps.

When these are not obtainable a ground connection can be made by taking a number of good turns around the conduit and then soldering the wire to the conduit. A better way would be to use a few T couplings on the system and to screw brass plugs to these and solder the ground wire to the plugs. Such

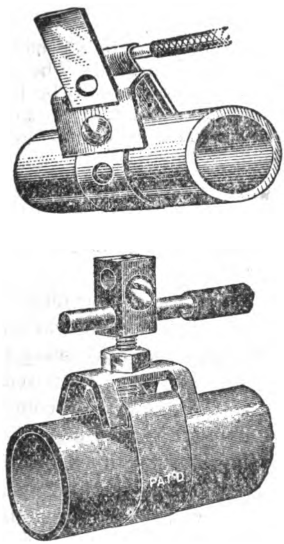


Figure 121.

couplings should be installed near outlets where they will not interfere much with "fishing."

If the ground wire has to be run for any great distance, it should be installed as though it were at all times alive, and should be kept away from inflammable material.

The method advised under 15 for grounding wires should be used. Where a 3-wire system is used, the best ground obtainable is the neutral wire of the system. When a ground is made to the neutral wire, it should be made back of the fuses on the service switch; never make the connection with the neutral inside of the service switch.

g. Junction boxes must always be installed in such a manner as to be accessible.

h. All elbows or bends must be so made that the conduit or lining of same will not be injured. The radius of the curve of the inner edge of any elbow not to be less than three and one-half inches. Must have not more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.

If more than four quarter bends are necessary, a junction box should be installed and the wires first pulled from one of the outlets to the junction box and then from the junction box to the other outlet.

Several methods are in use for bending conduit. With the lined conduit elbows and bends of various shapes can be obtained already bent, and it is much more satisfactory to use these, as considerable care must be exercised in making bends in order to keep the inside lining from coming loose from the pipe and causing trouble when "pulling in." To prevent this a suitable spiral spring is sometimes inserted into the conduit before bending. Plumbers working with lead pipe often use coarse sand to fill the pipe before bending. This is more particularly useful with special conduits such as brass tubing, which is sometimes used in showcase or window work and classed with fixtures.

With unlined conduits the bending is a simple matter, although here also care must be taken to see that the conduit does not bend flat. In a good bend the pipe retains its circular form throughout the bend, while, if the bend is poorly made, the pipe will assume an oval shape, flattening somewhat at the bend. The smaller size conduits can be bent in a common vise. This is best accomplished by gripping the pipe in the vise and making a small bend, then moving the pipe for a slight distance and bending again, and continuing until the desired shape is obtained. This method, however, is not to be recommended as, unless the wireman has had much experience on conduit work and is a very careful workman, the conduit will be more or less flattened at the bends.

Another method which can be used on small pipes is shown at *a* in Figure 122, using a three or four foot length of gas pipe or conduit with an ordinary gas pipe T on the end. This

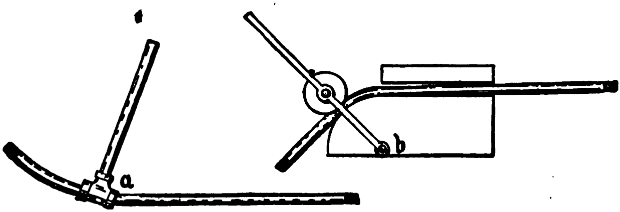


Figure 122.

is run over the conduit and gives sufficient leverage to make any bend.

A simple device used for bending conduits is shown at *b* in Figure 122. This is constructed of metal, the wheel being grooved to fit the pipe. A similar device minus the wheel and lever may be made up of two blocks of wood firmly fastened to a work bench. The pipe can be bent around this by hand using a piece of pipe large enough to slip over the conduit to prevent it bending in the wrong place. In lieu of the pipe just mentioned a tee as shown at *a* Figure 122 may be used.

For the larger conduits elbows can be obtained already bent, and the use of standard elbows for 90 degree bends in conduit 1 inch or larger is usually advisable. However, it is often necessary to make bends and offsets in large conduits. In order to bend large conduits some method of holding the conduit in place is necessary. This can often be done in new buildings by placing a heavy timber between the iron beams or columns and placing hard wood blocks on timber to hold the conduit in place.

Connections between the various lengths of conduit are made with the ordinary gas-pipe couplings. When the conduit comes from the factory each length of pipe is provided with a coupling at one end. (This practice is now being discontinued, the couplings being left off.) This coupling should be removed and the end of the conduit reamed out. The reaming

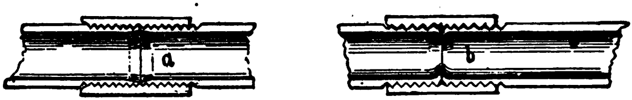


Figure 123.

should always be done so that there is considerable metal left at the end of the pipe, and it should never be carried so far as to leave only a sharp edge. If a thread is to be cut, it is good practice to take a couple of turns with the reamer after this has been done. The coupling can then be screwed on. When making the connection, the pipes should be screwed into the coupling so that the ends just "butt." Do not attempt to screw them too tight, or, in all probability, the thread on the end of the pipe will be turned in and close the opening. Figure 123, *a*, shows how a connection should be made. If lined conduit is not properly reamed and is screwed too tight the opening is often entirely closed or forced downward, as shown at *b*.

It is often necessary, especially in making changes in old installations, to fit pieces between two pipes, neither one of which can be turned so as to draw them together. In such cases a long thread is cut on one piece of the pipe and the coupling run back on it; when the pipes are butted together the coupling is run over the two pipes, thus connecting them. A locknut may be run upon either pipe and used to keep the coupling in place.

In running conduits avoid as much as possible passing through bath-rooms and other places where plumbers are likely to run their piping.

When practicable, conduits should be run so they will drain; for instance, where crossing a room from one side bracket to another, it is better to run along ceiling than along the floor. Conduits will sometimes become quite moist inside from condensation. Where there is any likelihood of this the ends may be sealed.

Figure 124 shows the wiring plan of a modern office building. It will be seen from a close examination of the plan that there are several novel features in the layout of the circuits. The particular building to which this plan refers is designed for use as separate small offices or shops or the whole floor may be arranged for one tenant.

In buildings of this class the final location of the outlets on the various floors is a subject of much uncertainty until the particular floor is rented and this may not be until after the rough work on the building is entirely completed. The usual method of placing conduit pipes together with switch and bracket outlets in partition walls necessitates either the altering of considerable conduit work to conform to the renting plans, or that only a small proportion of the conduit can be put in place when the first portion of the work is done.

With the layout shown by the floor plan no outlets or conduits are placed in any partitions. All circuits are carried to the outside walls of the building which, of course, are never altered. The conduits from the cutout center on each floor are large enough to carry additional circuits for future use and terminates in a 3-gang box. From this box conduits

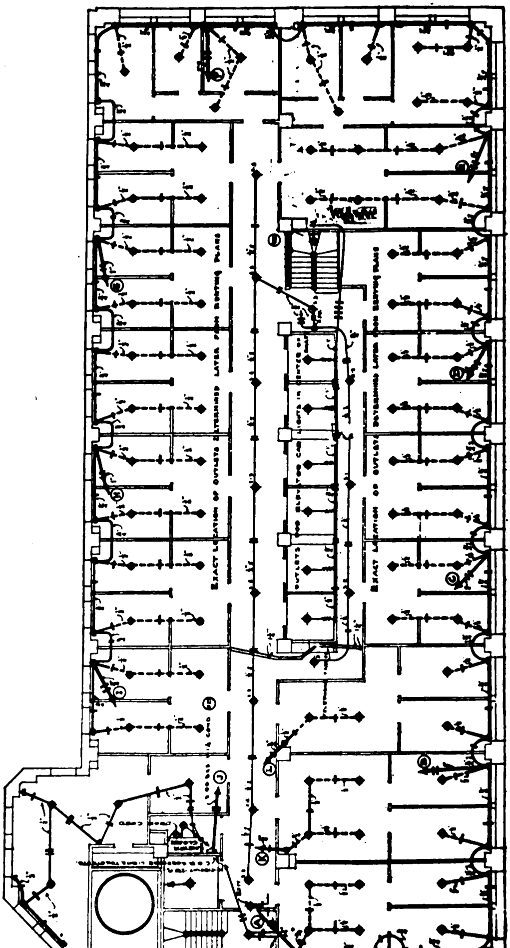

EXACT LOCATION OF OUTLETS DETERMINED LATER FROM ERECTING PLANS
EXACT LOCATION OF OUTLETS DETERMINED LATER FROM ERECTING PLANS

Figure 124.

extend on the ceiling in the direction of the first outlet. The conduit shown by the dotted lines is not run until the renting plans are available and the exact locations of ceiling outlets is secured. The 3-gang box referred to is arranged to be used for two switches and one receptacle or one switch and two receptacles, a special covering being provided so that these changes can be made at any time.

It will be noted that only two ceiling outlets are installed on each conduit run, the usual method of cross connecting a number of outlets in a conduit net is avoided. This arrangement permits the outlets to be moved after installation with a minimum of labor and damage to the tile ceiling.

Each of the conduit runs feeding towards the ceiling outlets contains a separate 2-wire circuit. This arrangement permits partitions to be run between these outlets and the space divided up between columns in almost any manner without affecting the metering arrangement.

With this wiring plan an unusually large percentage of conduit can be put in place when the work is first done and the final partition layout will not necessitate the changing of this pipe.

29. Metal Mouldings.

(See also No. 26 k to m. For construction of Mouldings see No. 60.)

a. Must be continuous from outlet to outlet, to junction boxes, or approved fittings designed especially for use with metal mouldings, and must at all outlets be provided with approved terminal fittings which will protect the insulation of conductors from abrasion, unless such protection is afforded by the construction of the boxes or fittings.

b. Such moulding where passing through a floor must be carried through an iron pipe extending from the ceiling below to a point five feet above the floor, which will serve as an additional mechanical protection and exclude the presence of moisture often prevalent in such locations.

In residences, office buildings and similar locations where appearance is an essential feature, and where the mechanical strength of the moulding itself is adequate, this ruling may be modified to require the protecting piping from the ceiling below to a point at least three inches above the flooring.

c. Backing must be secured in position by screws or bolts, the heads of which must be flush with the metal.

d. Must have the metal of moulding permanently and effectually grounded to water piping, gas piping, or suitable ground plate, provided that when connections are made to gas piping, they must be on the street side of the meter. If the metal moulding system consists of several separate sections, the sections must be bonded to each other and the system grounded, or each section may be separately grounded, as required above.

Metal mouldings and gas pipes must be securely fastened to outlet boxes, junction boxes and cabinets, so as to secure a good electrical connection. Moulding must be so installed that adjacent lengths of moulding will be mechanically and electrically secured at all points.

If metal moulding, couplings, outlet boxes, junction boxes, cabinets or fittings have protective coating of non-conducting material such as enamel are used, such coating must be thoroughly removed from threads of couplings and metal mouldings, and from the surfaces of boxes, cabinets and fittings, where the metal moulding or ground clamp is secured in order to obtain the requisite good connection. Grounded pipes should be cleaned of rust, scale, etc., at the place of attachment of the ground clamp.

Connection to grounded pipes and to metal mouldings must be exposed to view, or readily accessible, and must be made by means of approved ground clamps, to which the wires must be soldered.

Ground wires must be of copper, at least No. 10 B. & S. gage. They shall be protected from mechanical injury.

e. Must be installed so that for alternating systems the two or more wires of a circuit will be in the same metal moulding.

It is suggested that this be done for direct systems also, so that they may be changed to the alternating system at any time, induction troubles preventing such change if the wires are in separate mouldings.

Metal moulding is a comparatively recent development in wiring methods. It does away with a number of the objectionable features that exist in the case of wood moulding, very closely resembling conduit in point of safety from fire. At the same time it retains most of the useful features of wood moulding. Its use is bound to become more extensive as many cities are now prohibiting the use of wood moulding entirely.

It consists of a backing and a capping, both of metal, the backing being first fastened in place and the wires then laid in and covered by the capping. Figure 183 shows one form of metal moulding with some of the fittings.

The rules governing its installation are very similar to those governing the installation of conduit and the explanations made under the head of conduit will apply equally well here.

The thickness of metal not being as heavy as required for conduit it is more liable to mechanical injury and must therefore be protected on side walls. For the same reason its use is limited to circuits of not more than 660 watts (see Rule 26*l*), and not larger than 6 ampere fuses should ever be used for the circuit protection.

30. Fixtures.

(See also Nos. 24 e, 26 v to y and 55. For construction of Fixtures see No. 77.)

a. When supported at outlets in metal conduit, armored cable, or metal moulding systems, or from gas piping or any grounded metal work, or when installed on metal walls or ceilings, or on plaster walls or ceilings containing metal lath, or on walls or ceilings, in fireproof buildings, must be insulated from such supports by approved insulating joints placed as close as possible to the ceilings or walls. The insulating joint may be omitted in conduit, armored cable or metal moulding systems with straight electric fixtures in which the insulation of conductors is the equivalent of insulation in other parts of the system, and provided that approved sockets, receptacles or wireless clusters are used of a type having porcelain or equivalent insulation between live metal parts and outer metal shells, if any.

Gas pipes must be protected above the insulating joint by approved insulating tubing, and where outlet tubes are used they must be of sufficient length to extend below the insulating joint, and must be so secured that they will not be pushed back when the canopy is put in place.

Where insulating joints are required fixture canopies of metal in fireproof buildings must be thoroughly and permanently insulated from the walls or ceilings, and in other than fireproof buildings they must be thoroughly and permanently insulated from metal walls or ceilings or from plaster walls or ceilings on metal lathing.

Fixtures having so-called flat canopies, tops or backs, will not be approved for installation, except where outlet boxes are used.

The rule states very clearly what fixtures must be provided with insulating joints. The primary reasons for requiring an additional insulation in the case of fixtures are: The wire used is of small size and the insulation quite thin. In the wiring of some forms of fixtures this rather poorly insulated wire is drawn in around all sorts of bends and angles and is generally subject to great abuse. The ordinary brass shell socket has the inner threaded portion separated from the outside shell only by a thin piece of prepared paper.

It is therefore necessary to reduce the electrical strain on this insulation as much as possible and this is especially true of the insulation to ground.

Another reason for the additional insulation is to prevent a ground on one fixture from causing trouble on other fixtures. If, for instance, one fixture in a building were in contact with the positive wire of the system and another in contact with a negative wire, and the two fixtures connected direct to the gas piping, the two contacts or "grounds" would form a short circuit, the current flowing from one pole along the gas piping to the other. This becomes impossible when the fixtures are insulated from the piping, or conducting parts of ceilings.

Where a fixture is wired with a standard wire having at least 3/64th inch rubber insulation and where the sockets are of porcelain or have a porcelain lining between the current carrying parts and the outer shell the objectionable features stated above no longer exist and the insulating joint is not required.

Insulating joints are made in a variety of forms. The one shown at *a* Figure 125 is designed for use on a combination gas and electric fixture and is constructed so as to allow the gas to pass through. The insulating joint shown consists of malleable iron castings insulated with sheet mica

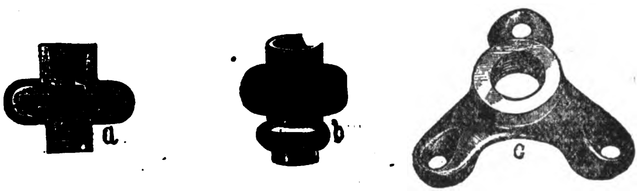


Figure 125.

and pressed together to form a joint strong enough to withstand the strains put on it when the fixture is screwed into place. A hard rubber shell extends from one metal part to the other and prevents leakage over the joint from condensation on its surface.

In installing fixtures white or red lead should never be used on the threads to make them gas tight as these are liable to run down on the inside of the insulating joint and bridge the mica insulation separating the two parts of the joint. An insulating cement should be used for this purpose.

The insulating joint shown at *b*, Figure 125 can be used with straight electric fixtures to attach the fixture to a stud in an outlet box or to a gas pipe.

Insulating joints should be placed as close as possible to the ceiling, so that there will be a minimum of exposed pipe above the joint. If the gas pipe has been left long so that the insulating joint comes some distance below the ceiling, it is necessary to protect the pipe above the joint either by using a porcelain tube which will fit over the pipe or by tap-

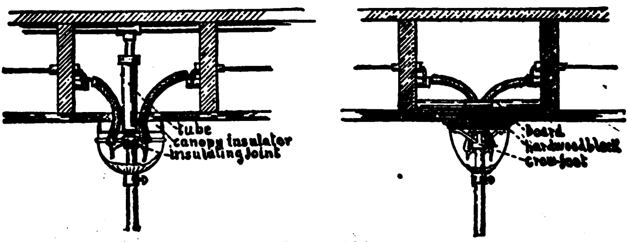


Figure 126.

ing the pipe thoroughly. Flexible tubing is also used. See Figure 126.

In connecting the fixture, care should be taken that the extra wire usually left for making the joint is twisted around the pipe below the insulating joint. If the wires at the outlet have been properly run, as shown in Figure 126, the flexible tubing, will extend to the bottom of the insulating joint.

When a straight electric fixture is to be installed on some grounded part of the building, a crowfoot, shown at *c*, Figure 125, can be fastened to the metal work and the fixture then connected with the insulating joint.

If the fixture is to be mounted on plaster, a hardwood block can be screwed to the wall or ceiling and a crowfoot screwed to this. The screws holding the crowfoot must not extend through the block. Such a case is illustrated at the right in Figure 126.

Before the plastering is put on, a board should be fastened between the joists, so that the wooden block may later be screwed to it. This is not absolutely necessary, as screws in lath will usually hold light fixtures. Heavy fixtures in old buildings can best be hung as shown at *b*, in Figure 127. This method is also used for ceiling fan motors. These motors must never be rigidly fastened, but should always be left free to swing and find their own centers.

In connection with open or moulding work, the canopies should always be cut out, so that the loom or moulding may

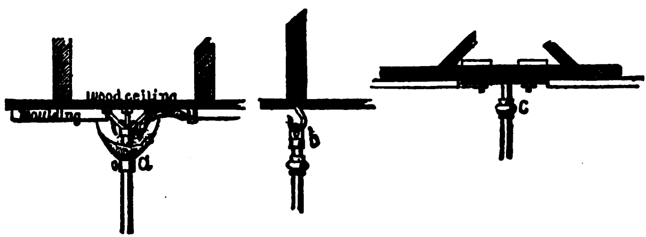


Figure 127.

enter them. On no account should wires be allowed to rest on sharp edge of canopy. See *a*, Figure 127.

Figure 127 illustrates at *c* how fixtures are fastened to tile ceilings, toggle bolts and a metal strip to which a piece of pipe is fastened being used.

The "construction rules" covering insulating joints require that the joint be capable of withstanding a voltage test of 4,000 volts. It is, of course, just as important that the canopies of fixtures be insulated from the walls or ceilings by an insulator capable of withstanding a like voltage test. Figure 128 shows a very acceptable type of canopy insulator, known as the "Bechtold" insulator. It is provided with a slot into which the edge of the canopy fits. Small holes are punched at regular intervals through the inside wall and, by means of a special tool, the brass canopy is pressed into these holes and the canopy insulator thus firmly held in place.

Strips of fiber riveted or otherwise rigidly fastened to the canopy are frequently used. These strips must be not less than 1/16 inch in thickness and of sufficient width to allow a space of not less than 3/16th inch between the metal canopy and the wall or ceiling. The fiber used for this purpose must

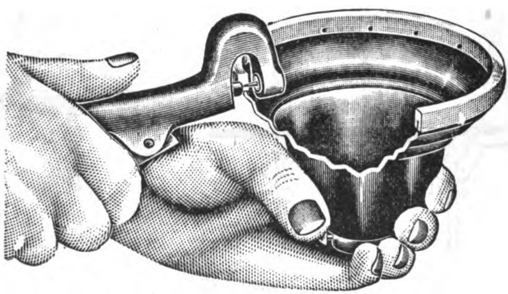


Figure 128.

be capable of withstanding the 4000 volt test previously described. Rivets or screws used to fasten the strips to the canopy should not be long enough to make contact with outlet boxes should these boxes be accidentally extended below the surface of the plaster.

When a wooden block is used to fasten the fixture to the wall the block may be made large enough so that the canopy will rest against it and no further insulation is necessary. The practice of fastening the canopy a short distance away from the wall or ceiling does not comply with the rule.

With fixtures having flat backs no provision is made for the fixture and line wire necessary to make a joint and for this reason canopies of this type must only be used with outlet boxes where the wires can be pushed back into the box when the fixture is fastened in place.

b. Must, when installed out doors, be of water-tight construction.

c. Must not, when wired on the outside, be used in show windows or in the immediate vicinity of especially inflammable stuff.

d. Must be free from short circuits between conductors and from contacts between conductors and metal parts of fixtures, and must be tested for such conditions before being connected to supply conductors.

Three tests should be made on each fixture before it is connected. If tests are not made until fixtures have been connected, it is often necessary to disconnect them again to determine whether a fault is in the fixture or in the wiring. Where there are several fixtures on one circuit and a short circuit should be discovered, it would also likely be necessary to disconnect several of them before the right one would be found.

A test for short circuit may be made, first, by connecting the two wires of a magneto to the two main wires at top of fixtures. If all sockets are properly connected and the wiring is clear, no ring will be obtained. If a ring is obtained, it indicates a short circuit.

Without changing connections each socket may now be tested for connections. While one man is operating the magneto, another may insert a screw-driver, jack-knife, or piece of wire into each socket in turn, thus connecting the two terminals and causing a ring of the magneto. Failure to obtain a ring would indicate an open circuit, which must, of course, be remedied.

The third test is made for "grounds." To make it, the two fixture wires are connected to one wire of the magneto and the other wire is connected to the metal of the fixture.

It is best to connect this wire to the iron piping, and not to the lacquered brass; the lacquer is often a very good insulator. If a ring is now obtained, it indicates that the insulation on a wire has been damaged, and that the bare wire is in contact with the fixture. This test can be made more thorough by working the accessible fixture wires back and forth during the test; sometimes a damaged portion of wire is not in contact with the metal of fixture while lying upon the floor, but may be brought in contact with it when hanging.

Fixtures that have been connected to the circuit and provided with insulating joints can be individually tested for "grounds," by connecting one wire of a magneto to the body of the fixture and the other, first to one, and then the other, of the circuit wires in the sockets. This test will detect a "ground" in a fixture without disconnecting it from the circuit.

A battery and bell or, better still, an incandescent light in series on a lighting circuit may be used for the testing in place of the magneto. A telephone receiver and a small dry battery such as is used in pocket flash lamps forms a compact and very useful testing device. This may be carried without inconvenience in the pocket and is available for testing at any time.

In connecting sockets to fixtures, it is advisable to connect them so that all protruding parts, as keys or receptacles for lamps, be of the same polarity, that is, all connected to the same main wire. This also applies to reflectors, border lights for theaters, encased in metal, etc. This will not lessen the liability of such parts to "ground," but lessens the chances of short circuits very much. Many "shorts" are brought about by the projecting brass lamp butts on fixtures being of opposite polarity. If they are of the same polarity, they will cause no trouble.

Special fixtures for show windows, etc, are often made up as shown in Figure 129. The construction shown at the left is more compart and neat, but requires more care in installing than the other, because of the edges of pipe in

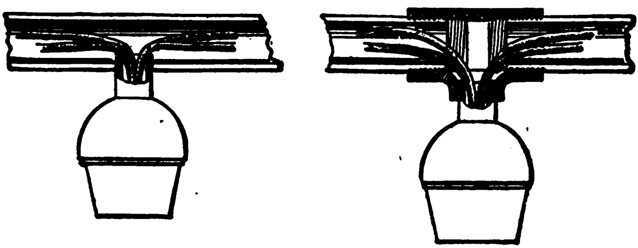


Figure 129.

contact with the wires. If very long fixtures of this kind are installed, it is advisable to insert insulating joints as often as practicable, even if necessary to run wires around them.

31. Sockets.

(For construction rules, see No. 72.)

a. In rooms where inflammable gases may exist the incandescent lamp and socket must be enclosed in a vapor-tight globe, and supported on a pipe-hanger, wired with *approved* rubber-covered wire soldered directly to the circuit.

Key sockets contain a switch (see No. 17 *b*).

In Figure 130, shows "vapor-tight" globes and Figure 131, *a* the method of suspending on a pipe hanger, the construction of which complies with the requirements of this rule. If moisture is present it is well to seal the upper end of the pipe with compound.

Key sockets must not be used in rooms where inflammable gases exist. If enclosed as required above they would be useless.

The reason for requiring vapor proof sockets to be supported on pipe hangers is that they will be rigid and cannot

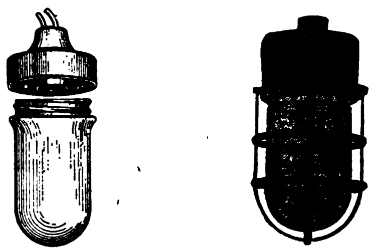


Figure 130.

be moved about sufficiently to come in contact with any object which might cause them to be broken. They should therefore be hung as high as circumstances will permit so that they will not be broken by being struck by anything carried through the room.

b. In damp or wet places "waterproof" sockets must be used. Unless made up on fixtures they must be hung by separate *stranded* rubber-covered wires not smaller than No. 14 B. & S. gage, which should preferably be twisted together when the pendant is over three feet long.

These wires must be soldered direct to the circuit wires but supported independently of them.

c. Key sockets will not be approved if installed over specially inflammable stuff, or where exposed to flyings of combustible material.

Waterproof sockets are constructed of porcelain, mica or moulded rubber as shown in Figure 132, and are not provided with keys, therefore the circuits to which they are connected must be controlled by switches. As a general rule these sockets are furnished with a short piece of stranded, rubber-covered wire extending through sealed holes in the top of the socket and the supporting wires are soldered to them. The

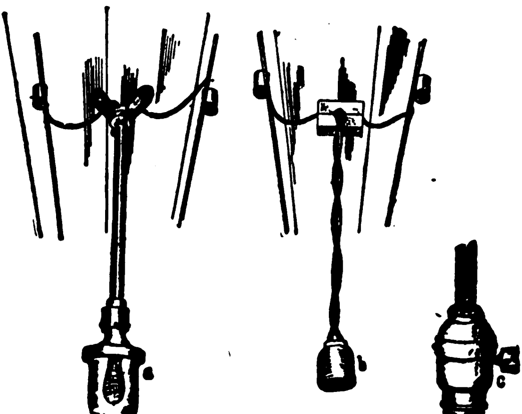


Figure 131.

method of suspending waterproof sockets varies with the conditions. Ordinarily, stranded rubber-covered wires of the proper length are suspended from single cleats as shown at *b,* in Figure 131, or, if the split knobs are large enough, the stranded wire may be supported from them. If the lamp is to be suspended only a short distance from the ceiling, where it will not be liable to be disturbed, it may be hung from two ordinary inch porcelain knobs, as shown in Figure 107. If cleats are used in a damp place for supporting the drop a half cleat must be provided back of the supporting cleat to give a one-inch separation, as required for wires in wet places.

Moulded rubber sockets should not be used where oils or greases are present as these have a deleterious effect on the composition of which the socket is made. In some loca-

Figure 132.

tions porcelain sockets in which sulphur is used will break from the expansion of the sulphur.

32. Flexible Cord.

(For Construction of Flexible Cord see No. 54.)

a. Must have an *approved* insulation and covering.

b. Must not, except in street railway property, be used where the difference of potential between the two wires is over 300 volts.

c. Must not be used as a support for clusters.

d. Must not be used except for pendants, wiring of fixtures, portable lamps or motors, and portable heating apparatus.

For all portable work, including those pendants which are liable to be moved about sufficiently to come in contact with surrounding objects, flexible wires and cables especially designed to withstand this severe service must be used.

When necessary to prevent portable lamps from coming in contact with inflammable materials, or to protect them from breakage, they must be surrounded with a substantial wire guard.

Under the heading of flexible cord are all the various types of flexible wires such as, common pendant cord, portable cord, stage cable, etc., and the construction rules, No. 54, should be very carefully read.

The practice of making pendant cords unnecessarily long and then looping them up with cord adjusters is strongly advised against. It offers a temptation to carry about lamps which are intended to hang freely in air. These adjusters should never be used where their use can be avoided and where they are used should only be placed on lamps which

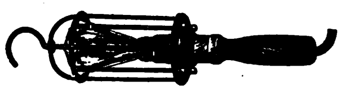


Figure 133.

will seldom need adjusting. The indiscriminate use of cord adjusters cannot be too strongly condemned as the constant rubbing of the adjuster soon destroys the insulation.

At *c*, Figure 131, shows a brass socket threaded for ⅜-inch pipe, and which is designed to be used with portable cord. Care should be taken in making up these sockets to see that the knot under the head of the socket has a good bearing surface so that it will not pull through the larger bushing, these portables being very apt to be jerked about.

A lamp guard to be of any value should be so constructed that the bulb of the lamp cannot come in contact with anything outside of the lamp guard; it should also protect the lamp from any sudden jar. The design of the guard should be such that it can be firmly attached to the socket so it will not work loose and come in contact with the live butt of the lamp or projecting threaded portion of the socket. See Figure 133.

e. Must not be used in show windows or show cases except when provided with an *approved* metal armor.

The great number of fires which have been caused by the use of flexible cord in show windows is sufficient argument against its use.

f. Must be protected by insulating bushings where the cord enters the socket.

g. Must be so suspended that the entire weight of the socket and lamp will be borne by some *approved* method under the bushing in the socket, and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding screws.

This is usually accomplished by knots in the cord inside the socket and rosette.

Special ceiling blocks or rosettes which facilitate the fastening of cords are on the market and should be used. In fastening the cord to the binding screws it is advisable to solder the ends of the wire. This, however, is not required by the rule (see No. 16 *c*), and should not be attempted unless great care is to be taken. If the ends of the cord are soldered stray strands of wire are not liable to come in contact with the brass shell of the socket and a much stronger and better contact is obtained at the binding screw. If a blow torch is used the small wires are very liable to be overheated and become brittle. The rubber insulation is also liable to be destroyed and it will soon crack and fall off. The soldering can best be done with a soldering iron or by dipping the ends in molten solder being careful to keep the insulating covering of the wires from becoming overheated.

It is also well to tape the ends of cords, leaving only just enough bare metal to go under the binding screws; the tape will hold the end of the braid and will confine any ends of wires which do not happen to come under the binding screws.

33. Arc Lamps on Constant-Potential Circuits.

(For construction of Arc Lamps see No. 74.)

a. Must have a cut-out (see No. 19 *a*) for each lamp or each series of lamps.

The branch conductors should have a carrying capacity about 50 per cent in excess of the normal current required by the lamp.

Figure 134 at the left gives a diagram of a constant potential arc circuit as generally used at present for enclosed arc

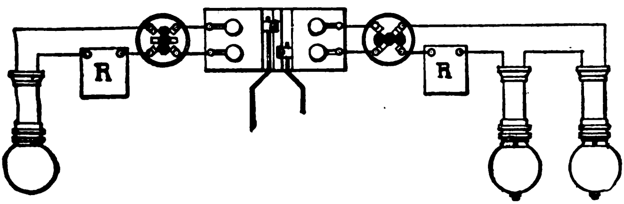


Figure 134.

lamps. Each arc lamp of this kind requires a pressure of 110 volts. A steadying resistance, R, is always placed in series with constant potential lamps, its object being to keep down the current while the lamp feeds. During the short time that the two carbons are together, the resistance of the lamp is so low that an enormous amount of current would flow were it not for this resistance. With most lamps this resistance is now installed in the hood. Since the rule requires a carrying capacity about 50 per cent in excess of the normal current for branch conductors, it would be well to provide this also for mains in such cases where groups of arc lamps are likely to be controlled by one switch and used together.

Figure 134 at the right shows a diagram of wiring for flaming arc lamps. Two lamps are usually run in series on 110 volts together with a steadying resistance.

b. Must only be furnished with such resistance or regulators as are enclosed in non-combustible material, such resistances being treated as sources of heat. Incandescent lamps must not be used for this purpose.

c. Must be supplied with globes and protected by spark arresters and wire netting around the globe, as in the case of series arc lamps (see No. 21).

Outside arc lamps must be suspended at least eight feet above sidewalks. Inside arc lamps must be placed out of reach or suitably protected.

d. Lamps when arranged to be raised and lowered, either for carboning or other purposes, shall be connected up with stranded conductors from the last point of support to the lamp, when such conductor is larger than No. 14 B. & S. gage.

This is required as a solid wire is apt to break from the constant swinging of the wires from the wind and from the raising and lowering of the lamp.

34. Mercury Vapor Lamps.

Enclosed Mercury Vapor Lamps.

a. Must have cut-out for each lamp or series of lamps except when contained in single frame and lighted by a single operation, in which case not more than five lamps should be dependent upon single cut-out.

b. Must only be furnished with such resistances or regulators as are enclosed in non-combustible cases, such resistances to be treated as sources of heat. In locations where these resistances or regulators are subject to flyings of lint or combustible material, all openings through cases must be protected by fine wire gauze.

The Cooper-Hewitt mercury vapor lamp is shown diagramatically in Figure 135. It consists of a long glass tube at one extremity of which is a metal reservoir partially filled with mercury. The lamp may be started by tilting the tube to a horizontal direction when the mercury flows out of the reservoir and forms a metallic stream connecting electrically the two terminals at each end of the lamp. As soon as the circuit is established the lamp is released and the mercury flows back into the reservoir but the current continues to flow through a path afforded by the mercury vapor. A greenish light is produced.

So far as the installation rules are concerned, this lamp is similar to the arc lamp. A resistance is always provided

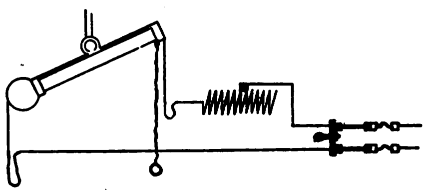


Figure 135.

to hold down the starting current when the lamp is short circuited by the stream of mercury and also to adjust the lamp to the proper current. Lamps are run either singly or two in series on 110 volts or four in series on 220 volts, and for photographic work they are mounted in a frame, but in accordance with the rule, more than five lamps must never be dependent on one cut-out.

High-Potential Vacuum Tube Systems.

c. The tube must be so installed as to be free from mechanical injury or liability to contact with inflammable material.

d. High-potential coils and regulating apparatus must be installed in approved steel cabinet not less than one-tenth inch in thickness; same to be well ventilated in such a manner as to prevent the escape of any flame or sparks, in case of burnout in the various coils. All apparatus in this box must be mounted on slate base and the enclosing case positively grounded. Supplying conductors leading into this high-potential case to be installed in accordance with the standard requirements governing low-potential systems, where such wires do not carry a potential of over 300 volts.

The Moore tube is the best known vacuum tube lighting system. This system of lighting has not come into any general use as it is still in a more or less experimental stage. It consists of a long gas tight tube carried around the space to be lighted. This tube is filled with a gas and the kind of gas used determines the character of the light. A high potential produced by specially designed transformers causes the current to flow through the gas in the tube.

35. Economy Coils.

a. Economy and compensator coils for arc lamps must be mounted on non-combustible, non-absorptive, insulating supports, such as glass or porcelain, allowing an air space of at least one inch between frame and support, and must in general be treated as sources of heat.

Economy or compensator coils are used in connection with arc lamps on multiple alternating current circuits. They serve the same purpose that the resistance coil does on the direct current arc lamp, but unlike the resistance they operate without the development of any great amount of heat. Some heat is, however, produced and these coils must be mounted away from woodwork or other combustible material.

36. Transformers.

(See also Nos. 11, 14, 15 and 45. For construction of Transformers see No. 81.)

Oil transformers:—

a. Must not be placed inside of any building except central stations and sub-stations, unless by special permission of the inspection department having jurisdiction.

Air cooled transformers:—

The following sections do not apply to apparatus or fittings, the operation of which depends either wholly or in part upon special transformers embodied in the devices, but all such apparatus or fittings must be submitted for special examination and approved before being used.

b. Must not be placed inside of any building excepting central stations and sub-stations, if the highest voltage of either primary or secondary exceeds 550 volts.

c. Must be so mounted that the case shall be at a distance of at least one foot from combustible material or separated therefrom by non-combustible, non-absorptive, insulating material, such as slate, marble or soapstone. This will require the use of a slab or panel somewhat larger than the transformer.

Oil cooled transformers are objectionable when installed inside of a building because the transformer has within it all that is necessary to both start a fire and to spread it after once started. For this reason the rule forbids them inside of the ordinary building. There are special conditions however, where oil cooled transformers must be used and in such cases the inspection department having jurisdiction must be consulted before installation.

37. Decorative Lighting Systems.

a. Special permission may be given in writing by the Inspection Department having jurisdiction for the temporary installation of *approved* Systems of Decorative Lighting, provided the difference of potential between the wires of any circuit shall not be over 150 volts and also provided that no group of lamps requiring more than 1,320 watts shall be dependent on one cut-out.

The Elblight decorative lighting system is approved for temporary installations. This system consists of a pair of heavy copper wires made up with fine copper strands. The wires are insulated and covered with an unsaturated braid. Receptacles for use with these wires are of porcelain, the terminals being two pointed pins which are stuck into the wire through the insulation, the pins entering the fine strands and making contact. The receptacles are held to the wire by porcelain pieces which clamp around the two wires. Receptacles may be attached to the wire at any point but in no case must more than 1320 watts be dependent on one cut-out.

Other decorative lighting systems are limited mostly to Christmas tree lights. There are a great number of these on the market and some of them are dangerous and should not be used. The list of approved fittings issued by the Underwriters laboratories should be consulted to determine those safe to use.

38. Theatre and Moving Picture Establishment Wiring.

All wiring, apparatus, etc., not specially covered by special rules herein given, must conform to the standard rules and requirements of the National Electrical Code, and the term "theatre" shall mean a building, or that part of a building regularly or frequently used for dramatic, operatic, moving picture or other performances or shows or which has a stage for such performances used with scenery or other stage appliances.

a. Services.

Where supply may be obtained from two separate street mains, two separate and distinct services must be installed, one service to be of sufficient capacity to supply current for the entire equipment of theatre, while the other service must be at least of sufficient capacity to supply current for all emergency lights. Where supply cannot be obtained from two separate sources, the feed for emergency lights must be taken from a point on the street side of main service fuses. By "emergency lights" are meant exit lights and all lights in lobbies, stairways, corridors, and other portions of theatre to which the public have access, which are normally kept lighted during the performance.

Where source of supply is an isolated plant within same building, an auxiliary service of at least sufficient capacity to supply all emergency lights must be installed from some outside source, or a suitable storage battery within the premises may be considered the equivalent of such service.

The spirit of this rule requires that the 'emergency" lighting system be kept entirely separate and distinct from the general lighting system. The emergency lighting system is designed to provide illumination sufficient for the audience to get from the auditorium to the outside of the building under any and all conditions liable to exist, even where the general illuminating system has been rendered useless. It is, therefore, of the utmost importance that the emergency system be made as reliable as is possible to the end that under no condition liable to exist will these lights be out of service. Figure 136 shows how this rule and also e-4 may be complied with. The emergency circuit should if possible be taken from mains that have no connection whatever with those supplying the auditorium and stage lights. The emergency mains must lead to the lobby and are not allowed to have any fuses except those at the street and those finally protecting the branch circuits. Under certain interpretation of this rule it is permissible to connect the two systems as shown by dotted lines. This is, however, bad practice, as the switch may be unintentionally left as shown in the cut and thus when the main fuse blows all of the lights will be out. In many cases this arrangement will be very costly, as often lobby and theater mains do not run close together. As there is to be only one fuse between street and cut-out box, the mains to lobby will have to be of the same size as the house mains.

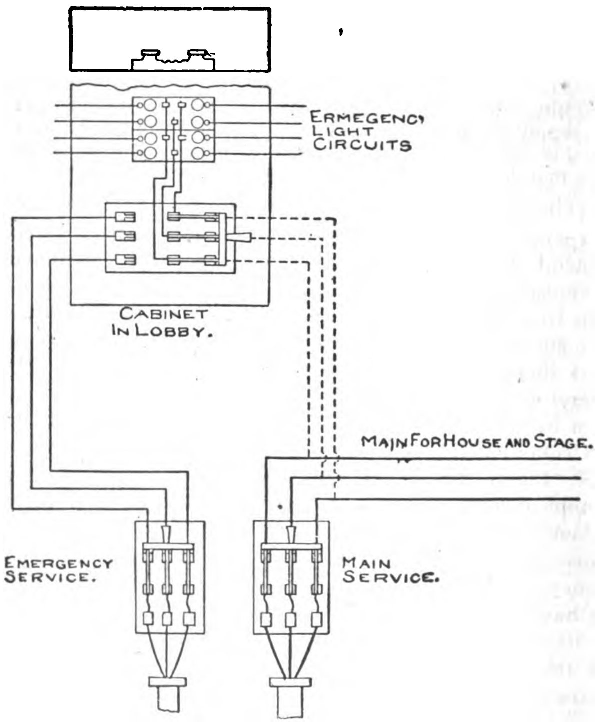


Figure 136.

It will be a good plan to arrange the house mains as shown in Figure 137. The double throw switch is provided merely to enable a quick re-illumination to take place in case one of the fuses were to blow. The switch is located at the electrician's station and it is but necessary for him to throw the switch to the other side to light up the house again.

In order to be certain that the fuse in the street will not blow, the wires between street and switch may be made sev-

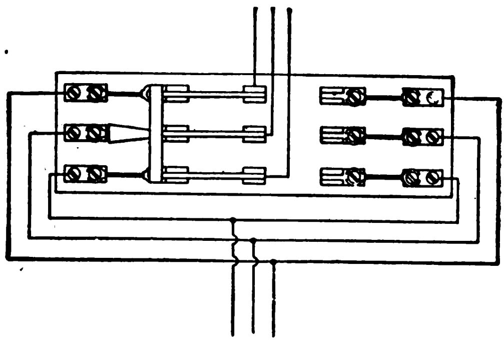


Figure 137.

eral sizes heavier than required and fused accordingly. Under such circumstances it is extremely unlikely that any but the fuse at the electrician's station will blow.

b. Stage.

All permanent construction on stage side of proscenium wall, except as hereinafter provided, must be approved conduit or armored cable.

c. Switchboards.

Must be made of non-combustible, non-absorptive insulating material, and where accessible from stage level must be protected by a suitable guard rail to prevent accidental contact with live parts on the board.

The switchboard of necessity being close to the stage proper is generally in such a position that persons leaving the stage pass directly in front of it. As the costumes worn by actors are very often made up of tinsel or other conduct-

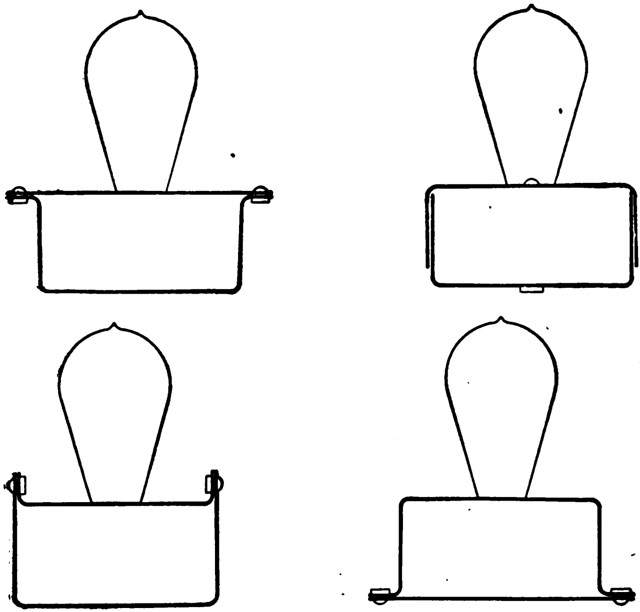


Figure 138.

ing material, and as various metal trappings are carried, it is essential that the guard rail be of such design as to prevent these materials from coming in contact with the live parts of the board. Where the guard rail is placed close to the board it is often advisable to provide a screen between the guard rail and the floor.

The best method, however, so far as safety is concerned is that of elevating the switchboard so that there can be no interference with it.

d. Footlights.

Must be wired in approved conduit or armored cable, each lamp receptacle being enclosed within an approved outlet box, or the lamp receptacles may be mounted in an iron or steel box, metal to be of a thickness not less than No. 20 U. S. Sheet Metal gage treated to prevent oxidation, so constructed as to enclose all the wires. Wires to be soldered to lugs of receptacles.

Must be so wired that no set of lamps requiring more than 1,320 watts nor more than 24 receptacles shall be dependent upon one cut-out.

Figure 138 shows a number of forms in which footlight troughs are made up. These troughs are constructed of No.

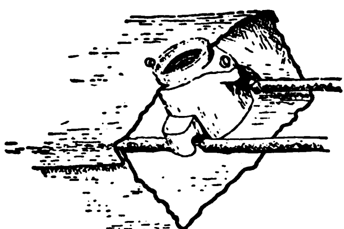


Figure 139.

20 U. S. sheet metal gage iron or steel, the receptacles being attached to the upper section as shown in Figure 139. The completed footlight strip is shown in Figure 140. These strips are combined in various ways to make up the foot-

light proper, their arrangement depending on the lighting effect desired. A common arrangement is shown in Figure 141, where two separate strips are used, one elevated above the other in order that the light from the back row of lamps will not be obstructed by the lamps in the front row. When

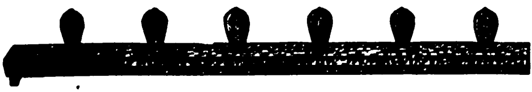


Figure 140.

footlights are installed in this manner more light is obtained when the clear lamps are placed in the front row, as only a small part of the light emitted from the colored lamps will be absorbed by passing through the clear globes, while, with the reverse arrangement, where the colored lamps are placed

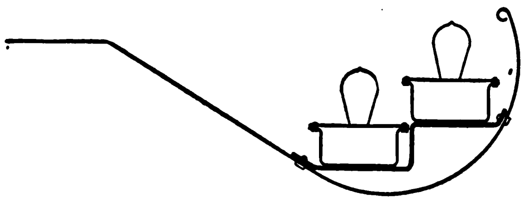


Figure 141.

in the front row, a considerable amount of light would be absorbed by the light from the clear lamps passing through the colored glass. Owing to the fact that the footlights are generally placed in troughs cut in the stage floor, thus bringing the lamps below the level of the stage floor, the placing of the white lamps in the lower row would not allow sufficient light to illuminate the back part of the stage, and for this reason where footlights are placed as shown in the figure it is the usual practice to place the white lights in the upper row.

Where all the lamps, both white and colored, are placed in one row, a reflector of the design shown in Figure 142 will materially increase the useful light.

Receptacles used in footlight construction must be of approved design and where the receptacle is fastened to the metal work with porcelain or metal threaded rings the receptacle must be so designed that it cannot be turned by the insertion or extraction of the lamp. This is generally accomplished by means of notches or projections on the porcelain of the receptacle and the metal should always be stamped to fit these parts.

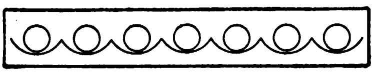


Figure 142.

Double braid, rubber covered wire must be used, and, with clip sockets, the wire must be soldered to the clip, in addition to being fastened by the binding screws. If the porcelain of the receptacle does not provide proper protection all exposed contacts, including the clips themselves, should be taped or covered with a suitable compound. Compound should not be used on border lights, as the heat from the lamps will cause the compound to melt and run down on the lamps. This also applies to any device of this form where the lamp hangs down, or below, the trough. In cases of this kind the clips should be taped, or, better, properly designed receptacles used.

The footlight circuits may be wired for a capacity of 1,320 watts, this allowing 24-16 c. p. lamps, 18-24 c. p. lamps, or 12-32 c. p. lamps of the carbon filament type on one circuit.

e. Borders and Proscenium Sidelights.

1. Must be constructed of steel of a thickness not less than No. 20 U. S. Sheet Metal gage, treated to prevent oxidation, be suitably stayed and supported, and so designed that flanges of reflectors will protect lamps.

2. Must be so wired that no set of lamps requiring more than 1,320 watts nor more than 24 receptacles shall be dependent upon one cut-out.

3. Must be wired in approved conduit or armored cable, each lamp receptacle to be enclosed within an approved outlet box, or the lamp receptacles may be mounted in an iron or steel box, metal to be of a thickness not less than No. 20 U. S. Sheet Metal gage treated to prevent oxidation, so constructed as to enclose all wires. Wires to be soldered to lugs of receptacles.

4. Must be provided with suitable guards to prevent scenery or other combustible material coming in contact with lamps.

5. Cables for borders must be of approved type and suitably supported; conduit construction must be used from switchboard to point where cables must be flexible to permit of the raising and lowering of border.

6. For the wiring of the border proper, wire with approved slow-burning insulation must be used.

7. Borders must be suitably suspended, and if a wire rope is used same must be insulated by at least one strain insulator inserted at the border.

The design and construction of border lights is similar to that just described for footlights with the exception of the arrangement of the strips and the kind of wire used. Border lights are suspended above the stage and are designed to throw the light downward and slightly to the back of the stage. To produce the proper lighting effects the border must be capable of adjustment, both as to its height above the stage and its position.

Figure 143 shows several forms of border lights.

Figure 144 shows a simple form of border light in common use. It will be noticed that the flange of the reflector is

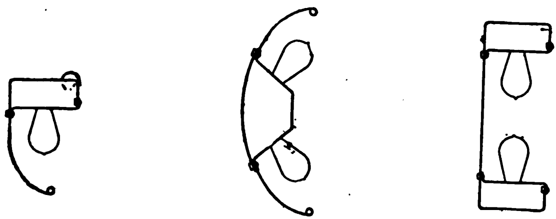


Figure 143.

carried around the lamps in such a manner as to protect them from accidental contact with the scenery.

Figure 145 shows a completed border light with one method of suspension. The iron bands to which are fastened the supporting chains are carried entirely around the border frame and serve as a means of attaching it to its support and at the same time provide mechanical protection

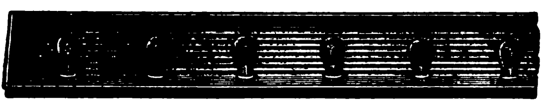


Figure 144.

for the lamps. These bands are placed from four to six feet apart.

The cables which carry current to the border lights are generally made up for each individual installation, the size and number of wires varying according to the number and combination of lamps used and the distance of the border from the stage switchboard or center of distribution.

See 54f for specifications governing border cables.

The cables should be long enough to allow the border to be lowered to within six or seven feet of the floor to permit of the necessary repairs and adjustments and the replacement of lamps.

"Take-up" devices, which are attached to the cable to take up the slack when the border is raised, should be fastened to the cable by some suitable device which will give a large

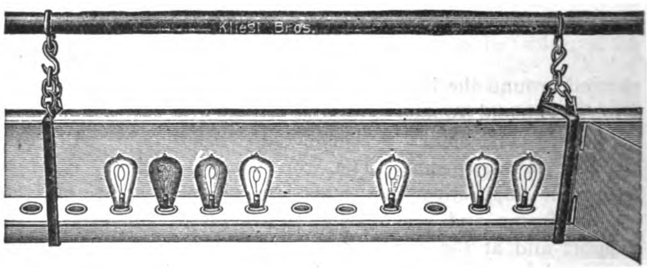


Figure 145.

bearing surface so that the insulation of the cable will not be injured. The practice of simply tying a rope around the cable is very bad, as the rope is sure to cut into the insulation.

As considerable heat is developed in a border light, due to the great number of lamps employed and to the position of the border itself, the rubber covering of the ordinary rubber covered wire would be very apt to become useless as an insulator, so that for this class of wiring slow-burning wire should be used. Specifications covering this wire are given under "Fittings."

Wire rope must be used for the suspension of the border lights. The rope should be of such size as to properly support the border with an ample safety factor. Generally three or four ropes are provided, each rope being fastened to a bridle which will distribute the strain uniformly along the length of the border frame. A strain insulator of the type shown in Figure 53 should be connected in the cable at the point where it connects to the border. The supporting cables are generally run to counterweights, hemp ropes fastened to either the counterweights or the border itself serving as a means to raise and lower the border. Where the border is small and of inconsiderable weight the wire rope is run directly to the point of fastening and the adjustments made with it direct. The supporting cables should be kept well oiled, dampness, especially that due to fire proofing of scenery is very likely to rust them.

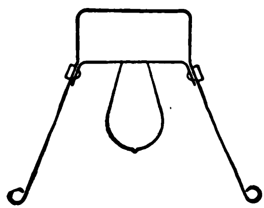


Figure 146.

Those lights placed at the stage opening on the stage side of the wall which separates the stage from the auditorium (prosecenium wall) are known as the proscenium side lights. They are constructed in the same manner as the footlights previously described, with the exception of the reflectors, which are of various shapes. Figure 146 shows a common form of proscenium side light.

The troughs are generally hinged so that they may be turned to illuminate any particular part of the stage, and special care should be exercised in placing them so that they cannot in any manner interfere with the operating of the curtain. It is sometimes advisable, especially in the case of vaudeville or burlesque houses, to provide a wire mesh screen for the protection of the lamps.

f. Stage and Gallery Pockets.

Must be of approved type, controlled from switchboard, each receptacle to be of not less than 35 ampere rating for arc lamps nor 15 amperes for incandescent lamps, and each receptacle to be wired to its full capacity. Arc pockets to be wired with wire not smaller than No. 6 B. & S. gage and incandescent pockets with not less than No. 12 B. & S. gage.

Plugs for arcs and incandescent pockets must not be interchangeable.

For the connection of portable apparatus on the stage or the gallery pockets are provided generally in the floor. These pockets contain receptacles into which the plugs connected to cables attached to the apparatus are inserted. The pockets should be made absolutely fireproof and the receptacles should be so installed that all live parts will be clear of the opening. It is now required to have stage plugs of different designs to be used in connection with arc and incandescent lights, so that it will be impossible to plug incandescent lights on arc light circuits. An arc light circuit requires a fuse of about forty amperes. Many times a single incandescent light is plugged into such a circuit. A short circuit occurring under these circumstances would be accompanied with disastrous results. Figure 147 shows a stage pocket with receptacles. The average stage pocket accommodates four receptacles.

g. Scene Docks.

Where lamps are installed in Scene Docks, they must be so located and installed that they will not be liable to mechanical injury.

As scene docks are often used for the storage of scenery and other stage paraphernalia and as lights are generally placed on the side walls, a substantial guard should be provided. This guard should be capable of standing considerable

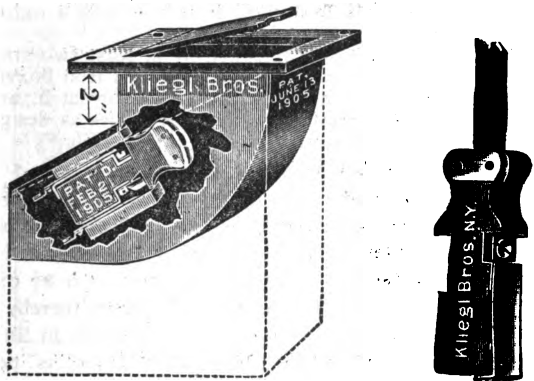


Figure 147.

hard usage and should be firmly attached. The ordinary lamp guard fastened to the socket or lamp itself is useless as a protection.

h. Curtain Motors.

Must be of ironclad type and installed so as to conform to the requirements of the National Electrical Code. (See No. 8.)

Rheostats used with curtain motors, if installed on the stage wall or in any other location outside of the motor room, should be entirely enclosed and well protected, so that nothing of an inflammable nature can come in contact with them.

i. Control for Stage Flues.

In cases where dampers are released by an electric device, the electric circuit operating same must be normally closed.

Magnet operating damper must be wound to take full voltage of circuit by which it is supplied, using no resistance device, and must not heat more than normal for apparatus of similar construction. It must be located in loft above scenery, and be installed in a suitable iron box with a tight self-closing door.

Such dampers must be controlled by at least two standard single pole switches mounted within approved iron boxes provided with self-closing doors without lock or latch, and located, one at the electrician's station and others as designated by the Inspection Department having jurisdiction.

The dampers referred to are ventilators arranged above the stage and scenery. In case of fire it is essential that these be opened immediately to allow smoke to escape and also to prevent the total consumption of oxygen in the building by the flames. This rapid consumption of oxygen, making it very difficult for people to breathe, thereby causing frantic efforts at inhalation, which result in inhaling large quantities of smoke and overheated air, is perhaps the main cause of the enormous death loss usual in theater fires.

Where current is obtained from an isolated plant which is shut down at night time and is not supplied with storage battery, or where alternating current is used, it is generally more satisfactory to use battery current for the operation of the damper, gravity cells being used for this purpose. Where the installation is supplied by a direct current system which is continuous the damper circuit may be taken directly from the system. Figure 148 shows an inexpensive form of damper control which is supplied by current from two or three cells of gravity battery. The lever arms are made from bar iron formed in the shapes shown. The magnet is of the type used in door openers and is enclosed in an iron box, that part of the enclosure immediately surrounding the magnet pole pieces being of brass. When the circuit is opened the armature falls and strikes the lower arm a sharp blow, thus releasing the damper rope. To close the damper the circuit is first closed, the magnet armature is pulled back in

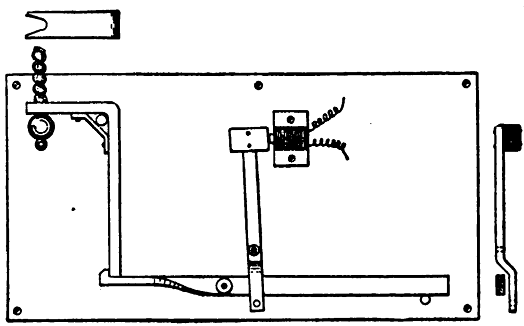


Figure 148.

place by the cord attached to the lower end of it, and the damper is closed, the ball in the damper rope engaging in the slot in the end of the lever arm.

j. Dressing Rooms.

Must be wired in approved conduit or armored cable. All pendant lights must be equipped with approved reinforced cord, armored cable, or steel armored flexible cord.
All lamps must be provided with approved guards.

Experience has proven it a difficult matter to arrange dressing rooms in such a way that actors cannot disarrange them and thus cause troubles of many kinds. One of the principal preventive devices is a lamp guard fastened to each socket in such a way that it cannot be removed without assistance from the house electrician. This will prevent the removal of the lamp and the substitution of a lamp of greater candle power or of the portable devices which many actors carry that require much more current. A lamp guard so arranged that it can be locked on will readily accomplish the purpose and such lamp guards are on the market.

The principal use of light in the dressing rooms is for the "make-up" of the actors. One light on each side of every mirror, suitably placed, with one or two lights for general illumination, are generally sufficient. A receptacle for curling iron connection can also be provided, but should also be under lock and key.

Dressing room circuits should be very lightly fused so that the use of electric irons will surely blow fuse.

k. Portable Equipment.

Arc lamps used for stage effects must conform to the following requirements:—

1. Must be constructed entirely of metal except where the use of approved insulating material is necessary.
2. Must be substantially constructed, and so designed as to provide for proper ventilation, and to prevent sparks being emitted from lamps when same are in operation, and mica must be used for frame insulation.
3. Front opening must be provided with a self-closing hinged door frame, in which wire gauze or glass must be inserted, except in the case of lens lamps, where the front may be stationary, and a solid door be provided on back or side.
4. Must be so constructed that neither carbons nor live parts will be brought into contact with metal of hood during operation, and arc lamp frames and standards must be so installed and protected as to prevent the liability of their being grounded.

5. Switch on standard must be so constructed that accidental contact with any live portion of same will be impossible.

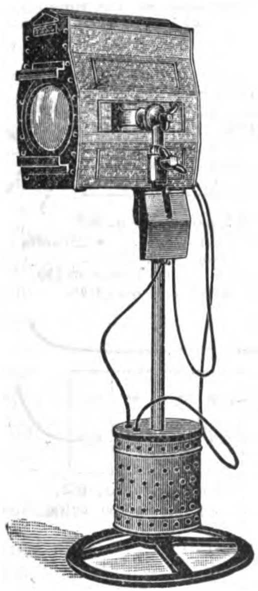


Figure 149.

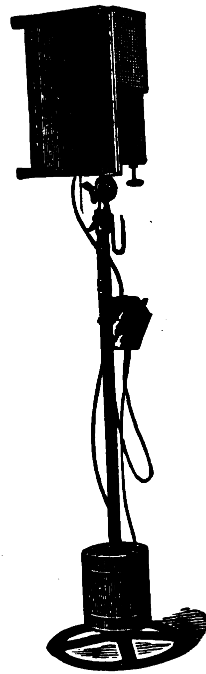
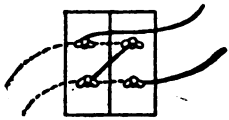


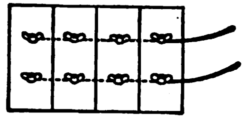
Figure 150.

6. All stranded connections in lamp and at switch and rheostat must be provided with approved lugs.

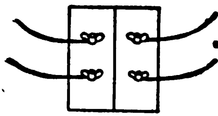
7. Rheostats must be plainly marked with their rated capacity in volts and amperes, and, if mounted on standard,



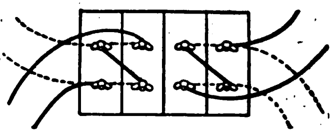
Rheostat No. 83.
Hard line—One lamp on 220 volts, 20 amperes.
Dotted line—One lamp on 110 volts, 30 amperes.



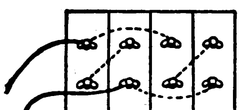
Rheostat No. 82.
One lamp on 110 volts, 60 amperes.



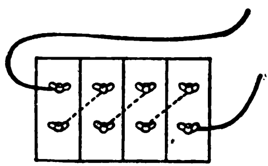
Rheostat No. 83.
Two lamps on 110 volts each, 15 amperes.



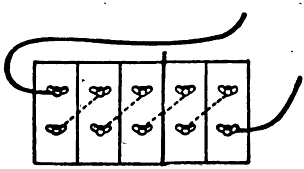
Rheostat No. 82.
Hard line—Two lamps on 220 volts each, 20 amperes.
Dotted line—Two lamps on 110 volts each, 30 amperes.



Rheostat No. 82.
One lamp on 220 volts, 35 amperes.



Rheostat No. 82.
One lamp on 450 volts, 20 amperes.



Rheostat No. 81.
One lamp on 550 volts, 22 amperes.

Figure 151.

must be raised to a height of at least three inches above floor. Resistance must be enclosed in a substantial and properly ventilated metal case which affords a clearance of at least one inch between case and resistance element.

8. A competent operator must be in charge of each arc lamp, except that one operator may have charge of two lamps when they are not more than ten feet apart, and are so located that he can properly watch and care for both lamps.

On the stage hand-feed arc lamps are used almost exclusively and an operator is always required to look after the lamps. The style of lamps generally used are shown in Figures 149 and 150. Figure 149 shows the focusing or spot lamp and Figure 150 the open box or olive lamp, which is used for general illumination. These arc lamps require a current of from 20 to 40 amperes and should be wired for accordingly.

Figure 151 shows diagrammatically a very useful form of rheostat for stage purposes. As most "shows" are constantly traveling, the apparatus carried by them should be adjustable in so far as voltage is concerned and also as to system, i. e., alternating or direct current. As will be seen from the figure, this rheostat lends itself to any voltage or system. This particular rheostat is manufactured by the Chicago Stage Lighting Co.

l. Bunches.

Must be substantially constructed of metal and must not contain any exposed wiring.

The cable feeding same must be bushed in an approved manner where passing through the metal, and must be properly secured to prevent any mechanical strain from coming on the connection.

The bunch light is used in various locations around the stage where only a small amount of illumination is required.

Bunches containing 200 32 c. p. lamps have been tried but none of them can equal the illumination obtained from arc lamps.

m. Strips.

Must be constructed of steel of a thickness not less than No. 20 U. S. Sheet Metal gage, treated to prevent oxidation, and suitably stayed and supported and so designed that flanges will protect lamps.

Cable must be bushed in a suitable manner where passing through the metal, and must be properly secured to prevent serious mechanical strain from coming on the connections.

Must be wired in approved conduit or armored cable, each lamp receptacle being enclosed within an approved outlet box, or the lamp receptacles may be mounted in an iron or steel box, metal to be of a thickness, not less than No. 20 U. S. Sheet Metal gage, treated to prevent oxidation, so constructed as to enclose all wires. Wires to be soldered to lugs of receptacles.

Strip lights are laid on the floor and hung on the scenery and are used to illuminate those parts of the scenery where the lights from the foots and borders are obstructed. Any of the forms shown in Figure 138 may be used for footlight construction. Reflectors are generally provided which serve to concentrate the light on the spot desired and to protect the lamps from accidental contact. Special care must be given to cables, where they leave strips; being portable, they soon suffer damage at these points.

n. Portable Plugging Boxes.

Must be constructed so that no current carrying part will be exposed, and each receptacle must be protected by approved fuses mounted on slate or marble bases and enclosed in a fireproof cabinet equipped with self-closing doors. Each receptacle must be constructed to carry thirty amperes without undue heating, and the bus-bars must have a carrying capacity equivalent to the current required for the total number of receptacles, and approved lugs must be provided for the connection of the master cable.

When a number of pieces of electrical apparatus are to be used at one time on the stage, instead of carring a separate

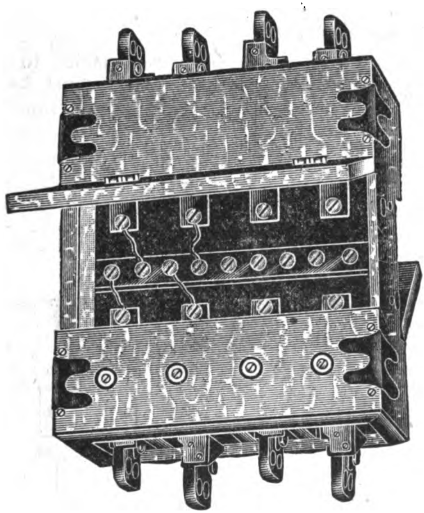


Figure 152.

cable from each piece of apparatus to a pocket, a portable plugging box or "spider box" is used. This is shown in Figure 152. One large cable is carried from the plugging box to a pocket or other convenient point of connection and the various pieces of apparatus connected to the plugging box by plugs and short cables. This greatly reduces the amount of cable used and allows of rapid assembly and removal.

o. **Pin Plug Connectors.**

Must be of an approved type, so installed that the "female" part of plug will be on live end of cable, and must be so constructed that tension on the cable will not cause serious mechanical strain on the connections.

p. **Portable Conductors.**

Flexible conductors used from receptacles to arc lamps, bunches and other portable equipments must be approved

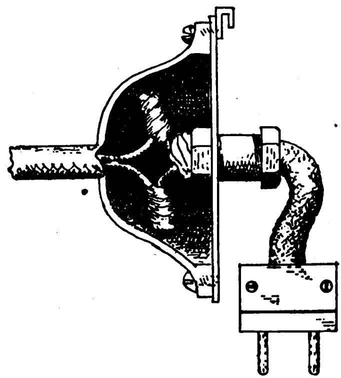


Figure 153.

stage cable except that for the purpose of feeding a stand lamp under conditions where conductors are not liable to severe mechanical injury, an approved reinforced cord may be used, provided cut-out designed to protect same is not fused over six amperes capacity.

q. **Lights on Scenery.**

Where brackets are used they must be wired entirely on the inside, fixture stem must come through to the back of the scenery and end of stem be properly bushed.

The usual method of complying with this rule is shown in Figure 153. Everything about the bracket is of metal and stage cable is used to make the connection to the outside.

r. String or Festooned Lights.

Wiring of same must be of approved type, joints to be properly made, soldered and taped, and staggered where practicable.

Where lamps are used in lanterns or similar devices, approved guards must be employed.

A good method of making tap joints in festoons is shown in Figure 154. The joints are made staggering and properly

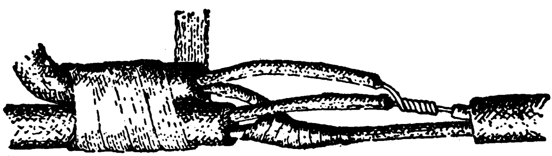


Figure 154.

soldered and taped with both rubber and friction taps. The cable which is tapped on is then carried along the main cable for three or four inches and securely taped. This removes nearly all the strain from the joints and prevents the wires from working loose.

s. Special Electrical Effects.

Where devices are used for producing special effects such as lightning, waterfalls, etc., the apparatus must be so constructed and located that flames, sparks, etc., resulting from the operation cannot come in contact with combustible material.

The necessity for electrical current in connection with stage effects has of late years been greatly reduced. Scenes and effects of almost any description can be produced by means of transparent films attached to and rotating in front of an arc lamp. Celluloid films, if they remain stationary exposed to the light of an arc lamp, may be ignited in two or three seconds and burn very rapidly. Gelatine is therefore always used.

Care must be exercised in the use of some of these effects, as the sudden and unexpected production of a fire effect or of a puff of smoke or momentary blaze such as would be produced by a short circuit might have a disastrous effect on the audience.

In Figure 155 a device is shown for producing lightning flashes. It consists of a solenoid, the core of which is attached to a lever fitted with a piece of carbon. The carbon rests on a piece of steel bar. When the circuit is closed the solenoid operates and raises the carbon from the piece of steel, a considerable flash resulting. The carbon continues to rise until the circuit opens, when it drops again, causing another flash, etc.

t. Auditorium.

All wiring must be installed in approved conduit, metal moulding or armored cable.

Exit lights must not have more than one set of fuses between same and service fuses.

Exit lights and all lights in halls, corridors or any other part of the building used by audience, except the general auditorium lighting, must be fed independently of the stage lighting, and must be controlled only from the lobby or other convenient place in front of the house. All fuses must be enclosed in approved cabinets.

The only fuses allowed on the exit light circuits are the branch fuses and the fuses at the service. This necessitates running the exit light main direct to the service, not changing size and not tapping onto any other main unless both mains are of equal carrying capacity.

All sockets used on the exit and emergency lighting should

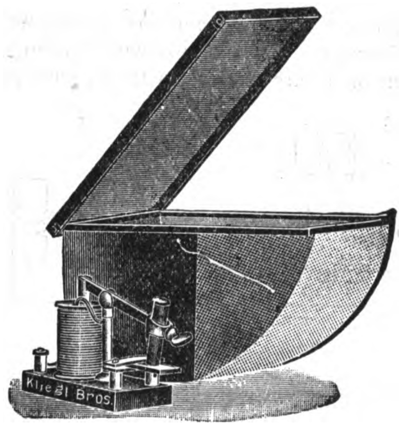


Figure 155.

be of the keyless type, so that they cannot be controlled from any point except the lobby.

u. Moving Picture Equipments.

1. *Arc Lamp Used as a Part of a Moving Picture Machine.*—Must be constructed. so far as practicable, similar to arc lamps of theatres, and wiring to same must not be of less capacity than No. 6 B. & S. gage.

In the typical moving picture house it is customary, where three wire service exists, to balance the arc lamp used for the picture machine against the incandescent lights used in house about as illustrated in Figure 156. It is a wise precaution to make connections to the arc as shown in the figure, placing the rheostat between the arc and the neutral wire. If this precaution is observed the operator will not be so likely to receive a shock when working on rheostat while it is alive. There will also be less liability of short circuits or trouble on the wiring between arc lamp and rheostat of which there is usually considerable. The asbestos wire entering arc lamp is likely to burn off at arc terminal perhaps, once per week and

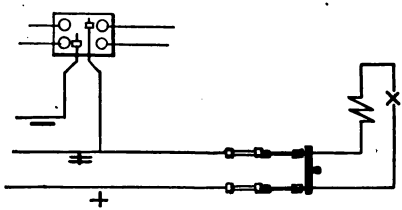


Figure 156.

operators are prone to carry as much slack on this as they dare.

2. *Rheostats.*—Must conform to rheostat requirements for theatre arcs.

3. *Top and Bottom Reels.*—Must be enclosed in steel boxes or magazines, each with an opening of approved construction at bottom or top, so arranged as not to permit entrance of flame to magazine. No solder is to be used in the construction of these magazines. The front side of each magazine must consist of a door spring-hinged and swinging horizontally, and be provided with a substantial latch.

The opening referred to that will not permit entrance of flame to magazine consists generally of two or more small rollers between which the film moves. These fit quite closely together and if well made and adjusted will not permit any fire to get by. Some of these as an additional precaution (which is much to be recommended) have in addition to the rollers a narrow tube of about 1½ inches in length through which the film is drawn. It has by repeated experiments been found impossible to draw a flaming piece of film through this aperture.

The two provisions of the rule concerning the door to the magazine do not seem to be of the wisest. Close observation of numerous operators at work reveals the fact that they are nearly all give to opening their magazines a little while before finishing a picture so as to be ready for a quick change of film. When the change of film is made they have the habit of resuming the run without stopping to close the doors at once and afterward forgetting about it. A spring hinge on door would naturally close it but the spring pressing against door is very annoying while changing film and threading and is therefore often found blocked. The net result of a spring hinge is often that the door is permanently blocked open. To avoid the unnecessary dangers careless operators subject their audiences to, in this way, magazines have been devised in which it is difficult or entirely impossible for a film to be run off unless the doors are securely locked.

If such magazines are not to be insisted upon it would seem preferable to hinge the door on the side at which the fire valves (as the rollers through which the film must pass are called) are located. A door arranged in this way and tightly fitting against the hinge side of the magazine may prevent flames following the film up to the fire valve from getting around into the magazine even if the door happens to be open.

4. *Automatic Shutter.*—Must be provided and must be so constructed as to shield the film from the beam of light whenever the film is not running at operating speed. Shutter must be permanently attached to the gate frame.

There are very few shutters in use at the present time that depend upon the motion of the film for their operation as this rule requires. Most of the shutters now in use admit light to strike the film when the machine is in motion. Some of them only require that the handle be pressed. There is, however, no guarantee that the film will be in motion whenever the machine is. Many of the old much used films have their sprocket holes so badly torn that the film may stop dead still even though the machine be running. It also happens that pieces of broken film become detached and stick at the edge of the light aperture long enough to become ignited and thus ignite the rest of the film even though it be in motion. Too much reliance must therefore never be placed upon any automatic light shutter. The chief reliance should always be in the magazines. If these are in good order and if all films in booth are well enclosed there can be no serious fire; it will be limited to a few feet of film between the upper and lower magazine.

5. *Extra Films.*—Must be kept in individual metal boxes equipped with tight-fitting covers.

This is a good rule and very few serious fires would result if it were rigidly obeyed. The rule could be improved by requiring that all of these individual boxes be kept in one place or within one box provided with well fitting cover arranged in some way that it cannot accidentally be left open. The operator is often hurried by manager to make change as rapidly as possible and neglects for the moment to close the box meaning to do so later and later often forgets.

The films should all be in one place because the chances of accidental ignition by careless use of matches, etc., are thereby reduced. Experience has shown that nearly always when one roll of film burns in a booth it sets fire to all the rest. This is probably due to the fact that the operator who is careless enough to let one roll ignite is also careless enough to leave all of his film lying about open.

6. *Machine Operation.*—Must be operated by hand. (Motor driven will not be permitted.)

The only reason for this rule is the fear that an operator would not pay close enough attention to the machine. Being compelled to operate by hand he must of course stay with the machine while otherwise he might be in a side room smoking or reading. There are moving picture machines which cannot be operated by hand and in connection with these the rule is generally ignored.

7. *Machine Enclosure.*—Machine must be placed in an enclosure or house made of suitable fireproof material; must be properly ventilated, properly lighted and large enough for operator to walk freely on either side of or back of machine. All openings into this booth must be arranged so as to be entirely closed by doors or shutters constructed of the same or equally good fire-resisting material as the booth itself. Doors or covers must be arranged so as to be held normally closed by spring hinges or equivalent devices.

The general lay out of a typical moving picture booth of the larger kind is given in Figure 157. In this booth are shown 2 moving picture machines; one stereoptican and one spot light. There is generally plenty of room available crosswise of the building but it is very desirable to limit the room lengthwise of the auditorium as much as possible on account of the seating capacity . Many of the booths have no other entrance but a trap door with a ladder leading into it. Such an arrangement is almost criminal. Film burns very rapidly and the gases are very poisonous and every possible facility should be given an operator to get away. The booth should be provided with a door on the side on which the cranks of machines are located so that it will be unnecessary for operator to pass around a burning film or that the likelihood of a burning film being located between himself and the door be reduced to a minimum.

The door to booth should be made to swing outward and be provided with spring hinges so that it will close itself. It

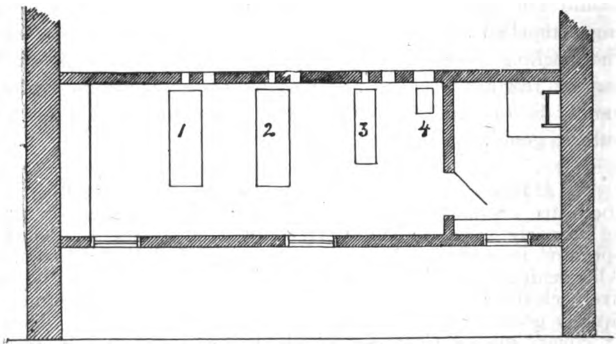


Figure 157.

should open upon a platform level with the floor of booth so as to facilitate the "get away" of the operator as much as possible. It is true that most of the fires that occur in connection with moving pictures machines are due to the carelessness of operators, but much of this carelessness is superinduced by the awkward conditions under which some of them are required to work. Many of them are today working in booths in which it is necessary to crawl on hands and knees to get about. The door should preferably be kept closed but on account of the heated conditions existing in most booths it would be found impossible to enforce such a rule. It will be well enough if arrangements are such that the door can be readily closed when a fire actually occurs. The door could to advantage be connected with the shutters in such a manner that closing the door would close the shutters. This would cause the shutters to be worked after each show and thus tend to keep them in working order.

The house should have a large vent communicating with the outside air in the ceiling and in order to make proper ventilation possible, there should be openings along bottom of booth. These openings to be covered by fine and strong wire mesh. Nearly all booths are sooner or later provided with fan motors and such a motor might as well be provided and placed so that it will exhaust air through the booth from the auditorium.

The wiring necessary to be introduced into the booth should be run along the ceiling in conduit to point directly above arc lamps so as to reduce amount of loose wire as much as possible. As the ends of wire connecting to arc lamp become very hot and in consequence must be often reconnected it is customary to install them of such a length that there may be considerable slack. This should be neatly coiled up near the ceiling.

The floor of booth should be arranged to be clear of everything. Take up magazines become deranged in one way or another quite frequently and in such a case there is likely to be much film run onto the floor. Many operators are careless enough to finish a show by running onto floor in such cases. When such an accident occurs there is likely to be a bad tangle of film and the less there is in the way on the floor the better it will be for all concerned. Any operator who has once had the experience of trying to straighten out a mess of film and get it back upon the reel while an impatient audience was clapping and calling to him to go on will appreciate this point.

The rheostat if placed within the booth is best suspended a foot or so from the ceiling wherever the height of booth will permit. If placed upon a shelf, rubbish is likely to be stored close to it.

There must be either two or three openings in booth for each moving picture machine. One of these is the "peek hole" through which the operator must view his picture, an-

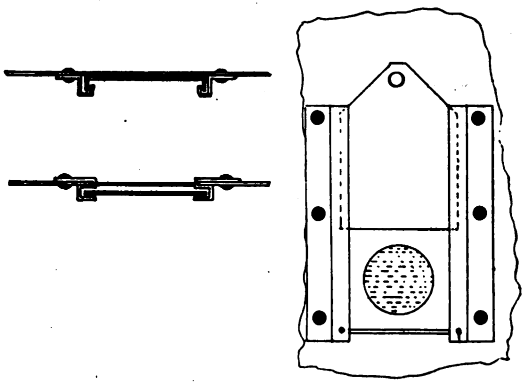


Figure 158.

other for the projection of the picture and generally a third through which the arc lamp may be used in connection with lantern slides. The two last mentioned openings may be very small, in fact, there are a number of booths which have no opening at all a funnel having been built which encloses the beam of light from the projecting lens until it passes out of the house. The "peek hole" may be closed with glass, wire glass being preferred.

The main care should be to keep the audience from discovering that there is a fire. In a properly arranged and ventilated booth the film will be burned in a few seconds and no further harm will be done unless the audience become frightened.

Where openings exist they must be provided with shutters by which they can be instantly closed in case of fire. The great majority of such shutters are arranged in guides as shown in Figure 158 and depend upon gravity to close them when the supports are released. A sliding shutter is preferable because a swinging shutter is more apt to meet with

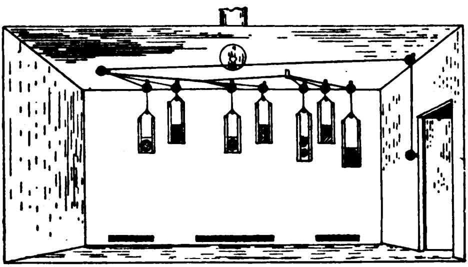


Figure 159.

obstructions in a crowded booth. A sliding shutter may be equipped with springs to help pull it down if desired. The guides for these shutters should be long enough so that the shutter will remain with its full length encased in them when open. The shutter should also be of a greater height than width. If it is wider than its height there is great possibility that it may hang a little lower on one side than on the other and become wedged in sliding down. Many booths are made up of thin metal. If shutters are placed upon such walls the guides should be strong enough to form substantial braces that will not easily bend and cause the shutter to stick.

Figure 159 shows an inside view of a booth and the arrangement of strings by which they are held open. The main string which supports all of them passes over the top of each machine and traverses the whole length of the booth. No matter in what portion a film may burn it will soon destroy the string and drop all of the shutters. As the string terminates at the door it is convenient for any one to release it when leaving the booth perhaps before the fire has reached the string. Fusible links of the proper kind in series with the string will be an improvement.

8. *Reels Containing Films Under Examination or in Process of Rewinding.*—Must be enclosed in magazines or approved metal boxes similar to those required for films in operation, and not more than two feet of film shall be exposed in booth.

This is one of the most important rules. Operators are very much in the habit of rewinding while operating and this is of course dangerous practice. As with the reels on machine so here it is of great importance to obtain magazines that cannot be operated with doors open. This will at least compel operators to keep films enclosed. Rewinding on open reel while operating machine means that film will be open in booth during the whole run of picture.

Before placing a new outfit in commission a thorough test as to its fireproof qualities should be made. Some old pieces of film should be procured and attempts made to work pieces of burning film through the five valves. No magazine in which this is possible should be used.

Next a piece of film should be threaded into the machine in its proper place and the light, strongly concentrated and with the strongest current ever used (50 to 60 amperes) allowed to strike as much of the light shutter and other parts of frame that may be within the possible range of focused light. The light should be left on each such place for a considerable time so that one feels assured that the film cannot be ignited in this way. If it is possible to ignite film in this manner the machine should be altered to make this impossible.

39. Outline Lighting.

Wiring (Other than Signs on Exterior of Buidings):—

a. Must be connected only to low-potential systems.

b. Open or conduit work may be used, but moulding will not be permitted.

c. For open work, wires must have an approved rubber insulating covering. Must be rigidly supported on non-combustible, non-absorptive insulators, which separate the wires at least one inch from the surface wired over, and must be kept apart at least two and one-half inches for voltages up to 300, and four inches for higher voltages.

Rigid supporting requires, under ordinary conditions where wiring over flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distances between supports should be shortened.

d. Where flexible tubing is required, the ends must be sealed and painted with moisture repellant, and kept at least one-half inch from surface wired over.

e. Wires for use in rigid or flexible steel conduit must comply with requirements for unlined conduit work. Where armored cable is used, the conductors must be protected from moisture by lead sheath between armor and insulation.

f. Must be protected by its own cut-out, and controlled by its own switch. Cut-outs, switches, time switches, flashers and similar appliances, must be of approved design, and must, if located inside the building, be installed as required by the code for such devices. If outside the building they must be inclosed in a steel or cast-iron box.

If a steel box is used, the minimum thickness of the steel must be 0.125 of an inch (No. 11 U. S. gage).

g. Boxes must be so constructed that when switch operates the blade shall clear the door by at least one inch, and they must be moisture proof.

h. Circuits must be so arranged that not more than

1,320 watts will be finally dependent upon a single cut-out; nor shall more than 66 sockets or receptacles be connected to single circuit.

i. Sockets and receptacles must be of the keyless porcelain type, and wires must be soldered to lugs on same.

Wiring for outline lighting is done either in conduit, armored cable or open work. If conduit is used the whole installation should be made watertight. Only such fittings should be used as are provided for threaded joints. The ordinary outlet box with locknut and bushing should never be

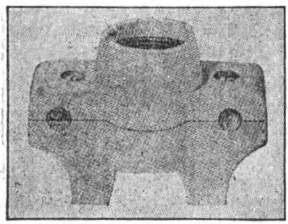


Figure 160.

Figure 161.

used for this purpose. If armored cable is used the wires must be covered by a lead sheath and watertight boxes must be used at outlets.

The cheapest construction consists of porcelain receptacles and open wiring. Rubber covered wire and receptacles which give a spacing of one inch from the surface wired over must be used. Receptacles designed for this use are shown in Figures 160 and 161. It will be noted that the wires are raised some distance from the surface on which it is placed to give the required one inch spacing.

All wires must be soldered to the binding posts of receptacles. This is required as the ordinary handling of the wire when installing is liable to loosen the wire from the binding posts if it is not soldered.

40. Car Wiring and Equipment of Cars.

a. Protection of Car Body, etc.

1. Under side of car bodies to be protected by *approved* fire-resisting, insulating material, not less than one-eighth inch in thickness, or by sheet iron or steel, not less than .04 inch in thickness, as specified in Section *a* 2, 3 and 4. This protection to be provided over all electrical apparatus, such as motors with a capacity of over 75 H. P. each, resistances, contactors, lightning arresters, air-brake motors, etc., and also where wires are run, except that protection may be omitted over wires designed to carry 25 amperes or less if they are encased in metal conduit.

2. At motors of over 75 H. P. each, fire-resisting material or sheet iron or steel to extend not less than 8 inches beyond all edges of openings in motors, and not less than 6 inches beyond motor leads on all sides.

3. Over resistances, contactors and lightning arresters, and other electrical apparatus, excepting when amply protected by their casing, fire-resisting material or sheet iron or steel to extend not less than 8 inches beyond all edges of the devices.

4. Over conductors, not encased in conduit, and conductors in conduit when designed to carry over 25 amperes, unless the conduit is so supported as to give not less than one-half inch clear air space between the conduit and the car, fire-resisting material or sheet iron or steel to extend at least 6 inches beyond conductors on either side.

The fire-resisting, insulating material or sheet iron or steel may be omitted over cables made up of flameproof braided outer covering when surrounded by one-eighth inch flameproof covering, as called for by Section *i*, 4.

5. In all cases fireproof material or sheet iron or steel to have joints well fitted, to be securely fastened to the sills, floor timbers and cross braces, and to have the whole surface treated with a waterproof paint.

6. Cut-out and switch cabinets to be substantially made of hard wood. The entire inside of cabinet to be lined with not less than one-eighth inch fire-resisting, insulating material which shall be securely fastened to the woodwork, and after the fire-resisting material is in place the inside of the cabinet shall be treated with a waterproof paint.

b. **Wires, Cables, etc.**

1. All conductors to be stranded, the allowable carrying capacity being determined by Table "A" of No. 18, except that motor, trolley and resistance leads shall not be less than No. 7 B. & S. gage, heater circuits not less than No. 12 B. & S. gage, and lighting and other auxiliary circuits not less than No. 14 B. & S. gage.

The current used in determining the size of motor, trolley and resistance leads shall be the per cent of the full load current, based on one hour's run of the motor, as given by the following table:—

Size each Motor.	Motor Leads.	Trolley Leads.	Resistance Leads.
75 H. P. or less	50%	40%	15%
Over 75 H. P.	45%	35%	15%

Approved fixture wire will be permitted for wiring *approved* clusters.

2. To have an insulation and braid *approved* for wires carrying currents of the same potential.

3. When run in metal conduit, to be protected by an additional braid.

Where conductors are laid in conduit, not being drawn through, the additional braid will not be required.

4. When not in conduit, in *approved* moulding, or in cables surrounded by one-eighth inch flame-proof covering, must be *approved* rubber covered (except that tape may be substituted for braid) and be protected by an additional flame-proof braid, at least one thirty-second inch in thickness, the outside being saturated with a preservative flame-proof compound, except that when motors are so enclosed that flame cannot extend outside of the casing, the flame-proof covering will not be required on the motor leads.

5. Must be so spliced or joined as to be both mechanically

and electrically secure without solder. The joints must then be soldered and covered with an insulation equal to that on the conductors.

Joints made with *approved* splicing devices and those connecting the leads at motors, plows or third rail shoes need not be soldered.

6. All connections of cables to cut-outs, switches and fittings, except those to controller connection boards, when designed to carry over 25 amperes, must be provided with lugs or terminals soldered to the cable, and securely fastened to the device, by bolts, screws or by clamping; or, the end of the cable, after the insulation is removed, shall be dipped in solder and be fastened into the device by at least two set screws having check nuts.

All connections for conductors to fittings, etc., designed to carry less than 25 amperes, must be provided with up-turned lugs that will grip the conductor between the screw and the lug, the screws being provided with flat washers; or by block terminals having two set screws, and the end of the conductors must be dipped in solder. Soldering, in addition to the connection of the binding screws, is strongly recommended, and will be insisted on when above requirements are not complied with.

This rule only to apply to circuits where the maximum potential is over 25 volts and current exceeds 5 amperes.

c. **Cut-outs, Circuit Breakers and Switches.**

1. All cut-outs and switches having exposed live metal parts to be located in cabinets. Cut-outs and switches, not in iron boxes or in cabinets, shall be mounted on not less than one-fourth inch fire-resisting, insulating material, which shall project at least one-half inch beyond all sides of the cut-out or switch.

2. Cut-outs to be of the *approved* cartridge or *approved* blow-out type.

3. All switches controlling circuits of over 5 ampere capacity shall be of *approved* single pole, quick break or *approved* magnetic blow-out type.

Switches controlling circuits of 5 ampere or less capacity may be of the *approved* single pole, double break, snap type.

4. Circuit breakers to be of *approved* type.
5. Circuits must not be fused above their safe carrying capacity.
6. A cut-out must be placed as near as possible to the current collector, so that the opening of the fuse in this cut-out will cut off all current from the car.

When cars are operated by metallic return circuits, with circuit breakers connected to both sides of the circuit, no fuses in addition to the circuit breakers will be required.

d. Conduit.

When from the nature of the case, or on account of the size of the conductors, the ordinary pipe and junction box construction is not permissible, a special form of conduit system may be used, provided the general requirements as given below are complied with.

1. Metal conduits, outlet and junction boxes to be constructed in accordance with standard requirements except that conduit for lighting circuits need not be over five-sixteenths inch internal diameter and one-half inch external diameter, and for heating and air motor circuits need not be over three-eighths inch internal diameter and nine-sixteenths inch external diameter, and all conduits where exposed to dampness must be water tight.
2. Must be continuous between and be firmly secured into all outlet or junction boxes and fittings, making a thorough mechanical and electrical connection between same.
3. Metal conduits, where they enter all outlet or junction boxes and fittings, must be provided with *approved* bushings fitted so as to protect cables from abrasion.
4. Except as noted in Section *i*, 2, must have the metal of the conduit permanently and effectively grounded.
5. Junction and outlet boxes must be installed in such a manner as to be accessible.
6. All conduits, outlets or junction boxes and fittings to be firmly and substantially fastened to the framework of the car.

e. Moulding.

1. To consists of a backing and a capping and to be constructed of fire-resisting, insulating material, except that

it may be made of hard wood where the circuits which it is designed to support are normally not exposed to moisture.

2. When constructed of fire-resisting, insulating material, the backing shall not be less than one-fourth inch in thickness and be of a width sufficient to extend not less than 1 inch beyond conductors at sides.

The capping, to be not less than one-eighth inch in thickness, shall cover and extend at least three-fourths inch beyond conductors on either side.

The joints in the moulding shall be mitred to fit close, the whole material being firmly secured in place by screws or nails, and treated on the inside and outside with a waterproof paint.

When fire-resisting moulding is used over surfaces already protected by one-eighth inch fire-resisting, insulating material no backing will be required.

3. Wooden mouldings must be so constructed as to thoroughly encase the wire and provide a thickness of not less than three-eighths inch at the sides and back of the conductors, the capping being not less than three-sixteenths inch in thickness. Must have both outside and inside two coats of waterproof paint.

The backing and the capping shall be secured in place by screws.

f. **Lighting and Lighting Circuits.**

1. Each outlet to be provided with an *approved* receptacle, or an *approved* cluster. No lamp consuming more than 128 watts to be used.

2. Curcuits to be run in *approved* metal conduit, or *approved* moulding.

3. When metal conduit is used, except for sign lights, all outlets to be provided with *approved* outlet boxes.

4. At outlet boxes, except where *approved* clusters are used, receptacles to be fastened to the inside of the box, and the metal cover to have an insulating bushing around opening for the lamp.

When *approved* clusters are used, the cluster shall be thoroughly insulated from the metal conduit, being mounted on a block of hard wood or fire-resisting, insulating material.

5. Where conductors are run in moulding the receptacles or cluster to be mounted on blocks of hard wood or of fireproof insulating material.

g. Heaters and Heating Circuits.

1. Heaters to be of *approved* type.

2. Panel heaters to be so constructed and located that when heaters are in place all current-carrying parts will be at least 4 inches from all woodwork.

Heaters for cross seats to be so located that current-carrying parts will be at least 6 inches below under side of seat, unless under side of seat is protected by not less than one-fourth inch fire-resisting, insulating material, or .04 inch sheet metal with 1 inch air space over same, when the distance may be reduced to 3 inches.

Truss plank heaters to be mounted on not less than one-quarter inch fire-resisting, insulating material, the legs or supports for the heaters providing an air space of not less than one-half inch between the back of the heater and the insulating material.

3. Circuits to be run in *approved* metal conduit, or in *approved* moulding, or if the location of conductors is such as will permit an air space of not less than 2 inches on all sides except from the surface wired over, they may be supported on porcelain knobs or cleats, provided the knobs or cleats are mounted on not less than one-fourth inch fire-resisting, insulating material extending at least 3 inches beyond conductors at either side, the supports raising the conductors not less than one-half inch from the surface wired over, and being not over 12 inches apart.

h. Air Pump Motor and Circuits.

1. Circuits to be run in *approved* metal conduit or in *approved* moulding, except that when run below the floor of the car they may be supported on porcelain knobs or cleats, provided the supports raise the conductors at least one-half inch from the surface wired over and are not over 12 inches apart.

2. Automatic control to be enclosed in *approved* metal box. Air pump and motor, when enclosed, to be in *approved*

metal box or a wooden box lined with metal of not less than one thirty-second inch in thickness.

When conductors are run in metal conduit the boxes surrounding automatic control and air pump and motor may serve as outlet boxes.

i. Main Motor Circuits and Devices.

1. Conductors connecting between trolley stand and main cut-out or circuit breakers in hood to be protected where wires enter car to prevent ingress of moisture.

2. Conductors connecting between third rail shoes on same truck, to be supported in an *approved* fire-resisting, insulating moulding, or in *approved* iron conduit supported by soft rubber or other *approved* insulating cleats.

3. Conductors on the underside of the car, except as noted in Section *i*, 4, to be supported in accordance with one of the following methods:—

a. To be run in *approved* metal conduit, junction boxes being provided where branches in conduit are made, and outlet boxes where conductors leave conduit.

b. To be run in *approved* fire-resisting, insulating moulding.

c. To be supported by insulating cleats, the supports being not over 12 inches apart.

4. Conductors with flameproof braided outer coverings, connecting between controllers at either end of car, or controllers and contactors, may be run as a cable, provided the cable where exposed to the weather is encased in a canvas hose or canvas tape, thoroughly taped or sewed at ends and where taps from the cable are made, and the hose or tape enters the controllers.

Conductors with or without flameproof braided outer covering connecting between controllers at either end of the car, or controllers and contactors, may be run as a cable, provided the cable throughout its entire length is surrounded by one-eighth inch flameproof covering, thoroughly taped or sewed at ends, or where taps from cable are made, and the flameproof covering enters the controllers.

Cables where run below floor of car may be supported by *approved* insulating straps or cleats. Where run above floor of car, to be in a metal conduit or wooden box painted on the inside with not less than two coats of flameproof paint, and where this box is so placed that it is exposed to water, as by washing of the car floor, attention should be given to making the box reasonably waterproof.

Canvas hose or tape, or flameproof material surrounding cables after conductors are in same, to have not less than two coats of waterproof insulating material.

5. Motors to be so drilled that, on double truck cars, connecting cables can leave motor on side nearest to king bolt.

6. Resistances to be so located that there will be at least 6 inch air space between resistances proper and fire-resisting material of the car. To be mounted on iron supports, being insulated by non-combustible bushings or washers, or the iron supports shall have at least 2 inches of insulating surface between them and metal work of car, or the resistances may be mounted on hard wood bars, supported by iron stirrups, which shall have not less than 2 inches of insulating surface between foot of resistance and metal stirrup, the entire surface of the bar being covered with at least one-eighth inch fire-resisting, insulating material.

The insulation of the conductor, for about 6 inches from terminal of the resistance, should be replaced, if any insulation is necessary, by a porcelain bushing or asbestos sleeve.

7. Controllers to be raised above platform of car by a not less than 1 inch hard wood block, the block being fitted and painted to prevent moisture working in between it and the platform.

j. Lightning Arresters.

1. To be preferably located to protect all auxiliary circuits in addition to main motor circuits.

2. The ground conductor shall be not less than No. 6 B. & S. gage, run with as few kinks and bends as possible, and be securely grounded.

k. General Rules.

1. When passing through floors, conductors or cables must be protected by *approved* insulating bushings, which shall fit the conductor or cable as closely as possible.

2. Moulding should never be concealed except where readily accessible. Conductors should never be tacked into moulding.

3. Short bends in conductors should be avoided where possible.

4. Sharp edges in conduit or in moulding must be smoothed to prevent injury to conductors.

41. Car Houses.

a. The trolley wires must be securely supported on insulating hangers.

b. The trolley hangers must be placed at such a distance apart that, in case of a break in the trolley wire, contact with the floor cannot be made.

c. Must have an emergency cut-out switch located at a proper place outside of the building, so that all the trolley wires in the building may be cut out at one point, and line insulators must be installed, so that when this emergency switch is open, the trolley wire will be dead at all points within 100 feet of the building. The current must be cut out of the building when not needed for use in the building.

This may be done by the emergency switch, or if preferred a second switch may be used that will cut out all current from the building, but which need not cut out the trolley wire outside as would be the case with the emergency switch.

d. All lamps and stationary motors must be installed in such a way that one main switch may control the whole of each installation, lighting and power independently of the main cut-out switch called for in Section *c.*

e. Where current for lighting and stationary motors is from a grounded trolley circuit, the following special rules to apply:—

1. Cut-outs must be placed between the non-grounded side and lights or motors they are to protect. No set or group of incandescent lamps requiring over 2,000 watts must be dependent upon one cut-out.
2. Switches must be placed between non-grounded side and lights and motors they are to protect.
3. Must have all rails bonded at each joint with a conductor having a carrying capacity at least equivalent to No. 0 B. & S. gage annealed copper wire,

and all rails must be connected to the outside ground return circuit by a not less than No. 0 B. & S. gage copper wire or by equivalent bonding through the track. All lighting and stationary motor circuits must be thoroughly and permanently connected to the rails or to the wire leading to the outside ground return circuit.

f. All pendant cords and portable conductors will be considered as subject to hard usage.

g. Must, except as provided in Section *e,* have all wiring and apparatus installed in accordance with the rules for constant-potential systems.

h. Must not have any system of feeder distribution centering in the building.

i. Cars must not be left with the trolley in electrical connection with the trolley wire.

Figure 162 shows the desired layout of switches as called for in this rule. Switch 1 when opened will disconnect all

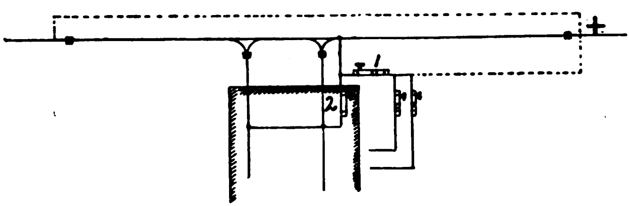


Figure 162.

the trolley wires within 100 feet of the building in either direction, as well as those in the house. If the house only is to be disconnected, switch 2 may be used. The broken lines indicate feeders run either underground or on poles to carry current around the building or supply power for light which may be desired to use while the trolley system is dead. The small black squares indicate the location of line insulators.

The above rule fits the car houses in the smaller cities better than it does those of large cities. In the latter the car house usually consists of a number of bays separated from each other by fire walls and constructed entirely of fireproof material. There is never anything in these bays that could burn with the exception of the cars themselves. It is advisable to arrange each bay with a service switch in addition to those called for by the rule. It will then be generally found that the main switch need not be used.

The rule allows the use of single pole switches on lighting from grounded trolley circuits. So long as the ground con-

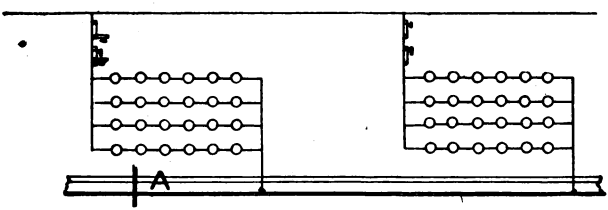


Figure 163.

nections are in good condition this is all that is necessary. In car houses, etc., where it is most likely that such method of lighting will be used the rails are generally relied upon to furnish at least part of the ground connection. These rails are often taken up or disconnected so that the breaking of the ground connection is always a possibility.

Referring to Figure 163, should such a break or bad condition exist at A and the group of lights at the right be turned on, a man working on the group of lights at the left might be severely injured even though the switch was disconnected.

Regarding the relative position of switch and fuses it will be noticed that the rule does not forbid the placing of the switch ahead of the fuses. Owing to the high potential generally used with trolley lines, and the fact that the switches and fuses are often handled by men who do not fully realize the life hazard, it is well to install the switch so that the fuse terminals will be dead when the switch is open.

As a curious illustration of what may sometimes occur from imperfect grounding the particulars of a recent electrical fire may be interesting. In a railway station, which was partly of metal and directly connected to a bridge crossing a trolley

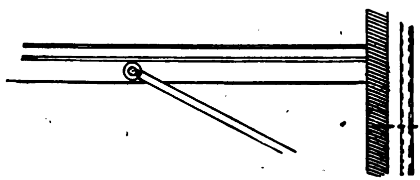


Figure 164.

line, there had been considerable annoyance from so-called "static" discharges for which no cause could be found. One of these discharges resulted in piercing a gas pipe and starting a fire. On investigation the conditions indicated diagrammatically in Figure 164 were found to exist and the cause of the fire determined.

The trolley passed under the metal work of the viaduct and within about one foot of the iron beams of the structure. The conditions were such that very frequently the trolley wheel would leave the trolley wire and immediately make contact with the metal of the structure above. This fact was evidenced by the presence of many burns on the metal work.

As a matter of fact the trolley wheel before coming in contact with the metal structure of the viaduct was disconnected from the current supply and, consequently, no current could have come from this source. But it must be borne in mind that the motor, at the moment of disconnection, becomes a generator and its fields are fully charged. The discharge of the fields induces an enormous voltage in the motor windings and this passes to the structure, which was poorly grounded, and finds a path to ground through the gas pipe previously mentioned finally piercing this pipe and starting the fire. Connecting the structure and the piping system by a suitable wire, as shown by broken lines in the figure, eliminated the trouble.

42. Lighting and Power from Railway Wires.

a. Must not be permitted, under any pretence, in the same circuit with trolley wires with a ground return, except in electric railway cars, electric car houses, power houses, passenger and freight stations connected with the operation of electric railways.

The use of the ordinary 550 volt trolley circuits for either lighting or power is a hazard. It is permitted only in the buildings belonging to the railway companies and it is questionable whether it should even be allowed there. There is not only a fire hazard but it is unsafe to life. A contact with any of these circuits while a person is standing on the ground will result in a severe shock if not in a fatality. Installations on systems of this type should be given careful consideration and all possible protections provided.

43. Electric Cranes.

All wiring, apparatus, etc., not specifically covered by special rules herein given, must conform to the Standard Rules and Requirements of the National Electrical Code, except that the switch required by No. 8 c for each motor may be omitted.

a. **Wiring.**

1. All wires except bare collector wires, those between resistances and contact plates of rheostats and those subjected

to severe external heat, must be approved, rubber-covered and not smaller in size than No. 12 B. & S. Insulation on wires between resistances and contact plates of rheostats must conform to Section *d,* while wires subjected to severe external heat must have approved slow-burning insulation.

2. All wires excepting collector wires and those run in metal conduit or approved flexible cable must be supported by knobs or cleats which separate them at least one inch from the surface wired over, but in dry places where space is limited and the distance between wires as required by Rule 26 *h* cannot be obtained, each wire must be separately encased in approved flexible tubing securely fastened in place.

Collector wires must be supported by approved insulators so mounted that even with the extreme movement permitted the wires will be separated at all times at least 1½ inches from the surface wired over. Collector wires must be held at the ends by aproved strain insulators.

3. Main collector wires carried along the runways must be rigidly and securely attached to their insulating supports at least every 20 feet, and separated at least 6 inches when run in a horizontal plane; if not run in a horizontal plane, they must be separated at least 8 inches. If spans longer than 20 feet are necessary the distance between wires must be increased proportionately but in no case shall the span exceed 40 feet.

4. Where bridge collector wires are over 80 feet long, insulating supports on which the wires may loosely lie must be provided at least every 50 feet.

Bridge collector wires must be kept at least 2½ inches apart, but a greater spacing should be used whenever it may be obtained.

5. Collector wires must not be smaller in size than specified in the following table for the various spans.

Distance between rigid supports.	Size wire required.
Feet.	B. & S.
0 to 30	6
31 to 60	4
Over 60	2

b. **Collectors.**

Must be so designed that sparking between them and collector wires will be reduced to a minimum.

c. **Switches and Cut-outs.**

1. The main collector wires must be protected by a cut-out and the circuit controlled by a switch. Cut-out and switch to be so located as to be easy of access from the floor.
2. Cranes operated from cabs must have a cut-out and switch connected into the leads from the main collector wires and so located in the cab as to be readily accessible to the operator.
3. Where there is more than one motor on a single crane, each motor lead must be protected by a cut-out located in the cab if there is one.

d. **Controllers.**

Must be installed according to No. 4, except that if the crane is located out doors the insulation on wires between resistances and contact plates of rheostats must be rubber where the wires are exposed to moisture and insulation is necessary and also where they are grouped. If the crane operates over readily combustible material, the resistance must be placed in an enclosure made of non-combustible material, thoroughly ventilated and so constructed that it will not permit any flame or molten metal to escape in the event of burning out the resistances. If the resistances are located in the cab, this result may be obtained by constructing the cab of non-combustible material and providing sides which enclose the cab from its floor to a height at least 6 inches above the top of the resistances.

e. **Grounding of Iron Work.**

The motor frames, the entire frame of the crane and the tracks must be permanently and effectually grounded.

Electric cranes are made in a variety of design and sizes, varying from the small crane operated from the ground and provided with a single motor, to the larger cranes with four or five motors.

The more common form of crane such as is used in large shops and other locations where it is necessary to move heavy loads consists of an iron bridge elevated some distance and carried on wheels which rest on tracks which are supported by the building walls or by special steel structures.

These cranes consist of three principal parts; the bridge, the trolley and the hoist.

The hoist is operated by a motor geared to a drum and is generally the heaviest motor on the crane.

The bridge motor moves the load in a transverse direction, or across the bridge.

The trolley motor moves the bridge along the runway.

These motors are controlled from a cab attached to the bridge the current being carried to the movable bridge, and from the bridge to the hoist motor, by trolley wires fastened along the steel work on which rest trolley wheels or shoes.

The usual processes in the operation of a crane are: the hoisting of the load, the movement of the load across the bridge and the movement of the bridge and load along the runway. The order of these operations may be reversed or they may occur together and it is possible to have all motors on a crane operating at one time. For this reason, and for the further reason that cranes are often overloaded, the wires should be of ample size to carry all motors running at one time.

It will be noted that the rule does not require a separate switch for each motor. There must be a main switch located in the cab (if there is one) which will cut off all motors and the starting devices. This switch must be double pole for direct current systems and three-pole for three-phase systems. There must also be a cut-out for each motor circuit; if the crane contains three motors there must be three cut-outs. For direct currents these cut-outs must be double-pole and for three-phase systems three-pole.

There must also be a cut-out and switch located within reach from the ground and so arranged that the entire crane including trolleys, cab, motor, etc., can be cut dead.

The rule describes the method of wiring allowed and these rules should be closely followed. Open wiring is very liable to mechanical injury. Conduit work will often save costly interruption of service and is to be recommended. The practice of wiring cranes with flexible tubing is not advisable for the same reason and for the further reason that it is almost as expensive as conduit work while its life is much shorter.

All collector wires must be supported at the ends by *approved* strain insulators. Insulators such as are shown at 2 Figure 53 should be used. Porcelain or glass circuit breakers such as shown in Figure 63 should not be used.

The collector wires are sometimes arranged to be fastened at each end by strain insulators and at intermediate points rest loosely on insulating supports. This is done to allow the use of contact shoes which make contact on the under side of trolley wires. Such shoes need not be adjustable as the free movement of the trolley wire allows for slight variations in the travel of the shoe. This construction is not in strict accordance with the rule which requires the trolley wire to be "rigidly" attached to the insulating supports. It is, however, extensively used. Supports as just described greatly lessen the tension on the wire, in fact relieve the tension just as much as though rigidly supported. The objection to this construction lies in the fact that if the trolley wire should break it would probably fall to the ground.

While the steel structure cannot be used as a return for the current it is liable at any time to become alive due to ground on the wiring system and as the structure is liable to be insulated from the earth on masonry columns it is very essential that it be effectively grounded.

HIGH-POTENTIAL SYSTEMS.

550 TO 3,500 VOLTS.

Any circuit attached to any machine or combination of machines which develops a difference of potential between any two wires of over 550 volts and less than 3,500 volts, shall be considered at a high-potential circuit, and as coming under that class, unless an approved transforming device is used, which cuts the difference of potential down to 550 volts or less. For 550 volt motor equipments a margin of ten per cent above the 550 volt limit will be allowed at the generator or transformer without coming under high-potential systems.

44. Wires.

(See also Nos. 16, 17 and 18. For construction rules see Nos. 49 and 50.)

a. Must have an *approved* rubber-insulating covering.

b. Must be always in plain sight and never encased, except as provided for in No. 8 *b*, or where required by the Inspection Department having jurisdiction.

c. Must (except as provided for in No. 8 *b*), be rigidly supported on glass or porcelain insulators, which raise the wire at least one inch from the surface wired over, and must be kept about eight inches apart.

Rigid supporting requires under ordinary conditions, where wiring along flat surfaces, supports at least about every four and one-half feet. If the wires are unusually liable to be disturbed, the distance between supports must be shortened.

In buildings of mill construction, mains of not less than No. 8 B. & S. gage, where not liable to be disturbed, may be separated about ten inches and run from timber to timber, not breaking around, and may be supported at each timber only.

d. Must be protected on side walls from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes) and extending not less than seven feet from the floor. When crossing floor timbers, in cellars, or in rooms where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness.

With the exception of series arc systems, which are fast going out of use, high potential wires are seldom brought into buildings. About the only cases where it is necessary to bring high tension wires into a building are for motor installations, which are provided for in No. 8 b, and installations where the transformers are placed inside of the building as provided in No. 45. In both of these cases special precautions are necessary.

45. Transformers. (When permitted inside buildings under No. 14.)

(See also Nos. 11, 14, 15 and 36. For construction of Transformers see No. 81.)

Transformers must not be placed inside of buildings without special permission from the Inspection Department having jurisdiction.

a. Must be located as near as possible to the point at which the primary wires enter the building.

b. Must be placed in an enclosure constructed of fire-resisting material; the enclosure to be used only for this purpose, and to be kept securely locked, and access to the same allowed only to responsible parties.

c. Must be thoroughly insulated from the ground, or permanently and effectually grounded, and the enclosure in which they are placed must be practically air-tight, except that it must be thoroughly ventilated to the outdoor air, if possible through a chimney or flue. There should be at least six inches air space on all sides of the transformer.

The practice of placing transformers inside of buildings should be discouraged. It is much better to place them on poles or in manholes or specially constructed buildings for in these locations they are less liable to be the cause of fatal accidents. When placed inside of a building the low potential mains should be fused outside of the transformer room and the installation should be otherwise arranged to make it unnecessary for any one other than an employe of the lighting company to ever enter the room and all keys to these rooms should be held by the companies employes only.

In the construction of transformer rooms inside of buildings it is well to provide for proper drainage. A ledge should be placed at all door openings of sufficient height to keep any oil which might leak out of the transformer from flowing into the building.

The rule allows either grounding or insulating of transformer case. It is generally considered, however, that the grounding is preferable as a safeguard to life. With a grounded case it is also impossible for a contact to be made between the high potential wires and the low potential wires through the case.

46. Series Lamps.

a. No multiple series or series multiple system of lighting will be approved.

b. Must not, under any circumtsances, be attached to gas fixtures

EXTRA-HIGH-POTENTIAL SYSTEMS.

Over 3,500 Volts.

Any circuit attached to any machine or combination of machines which develops a difference of potential, between any two wires, of over 3,500 volts, shall be considered as an extra-high-potential circuit, and as coming under that class, unless an approved transforming device is used, which cuts the difference of potential down to 3,500 volts or less.

47. Primary Wires.

a. Must not be brought into or over buildings, except power stations and sub-stations.

48. Secondary Wires.

a. Must be installed under rules for high-potential systems when their immediate primary wires carry a current at a potential of over 3,500 volts, unless the primary wires are installed in accordance with the requirements as given in No. 13 or are entirely underground, within city, town and village limits.

NOTICE—DO NOT FAIL TO SEE WHETHER ANY RULE OR ORDINANCE OF YOUR CITY CONFLICTS WITH THESE RULES.

Class D.

FITTINGS, MATERIALS AND DETAILS OF CONSTRUCTION.

ALL SYSTEMS AND VOLTAGES.

The following rules are but a partial outline of requirements. Devices or materials which fulfill the conditions of these requirements and no more, will not necessarily be acceptable. All fittings and materials should be submitted for examination and test before being introduced for use.

Insulated Wires—Rules 49 to 57.

49. General Rules.

a. Copper for insulated solid conductors of No. 4 B & S. gage and smaller must not vary in diameter more than .002 of an inch from the standard. On solid sizes larger than No. 4 B. & S. gage the diameter shall not vary more than one per cent from the specified standard. The conductivity of solid conductors shall not be less than 97% of that of pure copper of the specified size.

In all stranded conductors the sum of the circular mils of the individual wires, shall not be less than the nominal circular mils of the strand by more than one and one-half per cent. The conductivity of the individual wires in a strand shall not be less than is given in the following table, which applies to tinned conductors:—

Number.	Per cent.
14 and larger	97.0
15	96.8
16	96.6
17	96.4
18	96.2
19	96.0
20	95.8
21	95.6
22	95.4
23	95.2
24	95.0
25	94.8
26	94.6
27	94.4
28	94.2
29	94.0
30	93.8

The Standard for diameters and milages shall be that adopted by the American Institute of Electrical Engineers.

b. Wires and cables of all kinds designed to meet the following specifications must have a distinctive marking the entire length of the coil so that they may be readily identified in the field. They must also be plainly tagged or marked as follows:—

1. The maximum voltage at which the wire is designed to be used.
2. The words "National Electrical Code Standard."
3. Name of the manufacturing company and, if desired, trade name of the wire.
4. Month and year when manufactured.
5. The proper type letter for the particular style of wire or cable as given for each type of insulation in Nos. 50 to 57 inclusive.

Wires described under No. 53 need not have the distinctive markings, but are to be tagged.

50. Rubber-Covered Wire.

a. Copper for conductors must be thoroughly tinned.

Insulation for voltages, 0 to 600 inclusive.

b. The insulation must consist of a rubber compound, homogeneous in character, adhering to the conductor or to the separator, if one is used, and of a thickness not less than that given in the following tables, Sections *e* and *f*.

Measurements of insulating wall are to be made at the thinnest portion of the dielectric.

c. Any one foot sample of completed covering must show a dielectric strength sufficient to resist throughout five minutes the application of an electro-motive force proportionate to the thickness of insulation in accordance with the following table:—

Thickness in 64ths inches.	Breakdown test on 1 foot.
1	3,000 volts A. C.
2	6,000 " "
3	9,000 " "
4	11,000 " "
5	13,000 " "
6	15,000 " "
7	16,500 " "
8	18,000 " "
10	21,000 " "
12	23,500 " "
14	26,000 " "
16	28,000 " "

The source of alternating electro-motive force shall be a transformer of at least one kilowatt capacity. The application of the electro-motive force shall first be made at 3,000 volts for five minutes, then the voltage increased by steps of not over 3,000 volts, each held for five minutes, until the rupture of the insulation occurs. The tests for dielectric strength shall be made on a sample wire which has been immersed in water for seventy-two hours. One foot of the wire under test is to be submerged in a conducting liquid held in a metal trough, one of the transformer terminals being connected to the copper of the wire and the other to the metal of the trough.

d. Every length of completed wire or cable must be tested after not less than 12 hours immersion in water, and while still immersed by the application for one minute of an alternating current voltage derived from apparatus of ample capacity, the test voltages to be those given in the tables of Sections *e* and *f*.

After this voltage test every length of completed wire or cable while still immersed must show an insulation resistance after one minute electrification not less than the values given in Sections *e* and *f*.

Any length of completed wire or cable may be tested during 30 days immersion in water, and must show not less than 50 per cent of the insulation resistance required after the 12 hours' immersion.

The results of insulation test at different temperatures to be reduced to a basis of 60 degrees F. (15.5 degrees C.) by using the multipliers in the following table:—

Temp. Degs. Fahr.	Multiplier.
50-52	.69
53-55	.78
56-58	.88
59-61	1.00
62-64	1.12
65-67	1.27
68-70	1.43
71-73	1.60
74-76	1.81
77-79	2.04
80-82	2.29
83-85	2.58

e. Thickness of insulation, voltage tests and minimum insulation resistance to be in accordance with the following tables. The test voltages are to be for one minute. The insulation resistances are after one minute electrification and at 60 degrees Fahr. (15.5 C.)

Tests on Completed Lengths 0-600 Volt Class.

Type Letters R. S.

Size	Thickness in 64ths inches.	Megohms per mile after 12 hrs. immersion.	Voltage Test one minute.
14	3-64	300	1,500
12	3-64	250	1,500
10	3-64	225	1,500
8	3-64	200	1,500

Size	Thickness in 64ths inchs.	Megohms per mile after 12 hrs. immersion.	Voltage Test one minute.
6	1-16	200	2,000
4	1-16	150	2,000
2	1-16	125	2,000
1	5-64	150	2,500
0	5-64	125	2,500
00	5-64	125	2,500
000	5-64	100	2,500
0000	5-64	100	2,500
225,000 C. M.	3-32	100	3,000
300,000 C. M.	3-32	100	3,000
400,000 C. M.	3-32	100	3,000
500,000 C. M.	3-32	100	3,000
600,000 C. M.	7-64	100	3,500
700,000 C. M.	7-64	100	3,500
800,000 C. M.	7-64	100	3,500
900,000 C. M.	7-64	100	3,500
1,000,000 C. M.	7-64	100	3,500
1,250,000 C. M.	1-8	100	3,500
1,500,000 C. M.	1-8	75	3,500
1,750,000 C. M.	1-8	60	3,500
2,000,000 C. M.	1-8	50	3,500

f. **Tests on completed lengths 601 to 7,000 Volt.**

Max. Operating Voltage.
1,500 V. Type Letters R. S.—15.

Size.	Thick Ins.	Ins. Res. Meg.	Volts Test.
B. & S. Gage			
14-8	1-16	600	4,000
7-2	5-64	300	4,000
1-0000	3-32	200	4,000
C. M.			
225,000-500,000	7-64	175	4,000
525,000-1,000,000	1-8	150	4,000
Over 1,000,000	9-64	100	4,000

Max. Operating Voltage.

2,500 V. Type Letters R. S.—25.

Size. B. & S. Gage	Thick Ins.	Ins. Res. Meg.	Volts Test.
14-8	3-32	700	6,250
7-2	3-32	350	6,250
1-0000	7-64	250	6,250
C. M.			
225,000-500,000	1-8	200	6,250
525,000-1,000,000	9-64	175	6,250
Over 1,000,000	10-64	125	6,250

Max. Operating Voltage.

3,500 V. Type Letters R. S.—35.

Size. B. & S. Gage	Thick Ins.	Ins. Res. Meg.	Volts Test.
14-8	4-32	850	8,750
7-2	4-32	450	8,750
1-0000	4-32	300	8,750
C. M.			
225,000-500,000	9-64	225	8,750
525,000-1,000,000	10-64	200	8,750
Over 1,000,000;	11-64	150	8,750

Max. Operating Voltage.

5,000 V. Type Letters R. S.—50.

Size. B. & S. Gage	Thick Ins.	Ins. Res. Meg.	Volts Test.
14-8	6-32	1,000	12,500
7-2	6-32	650	12,500
1-0000	6-32	450	12,500
C. M.			
225,000-500,000	6-32	300	12,500
525,000-1,000,000	6-32	225	12,500
Over 1,000,000	7-32	175	12,500

Max. Operating Voltage.

7,000 V. Type Letters R. S.—70.

Size.	Thick Ins.	Ins. Res. Meg.	Volts Test.
B. & S. Gage			
14-8	8-32	1,200	17,500
7-2	8-32	800	17,500
1-0000	8-32	550	17,500
C. M.			
225,000-500-000	8-32	400	17,500
525,000-1,000,000	8-32	275	17,500
Over 1,000,000	9-32	200	17,500

g. All physical tests to be made at a temperature between 60 degrees and 90 degrees Fahrenheit. All test samples to be kept at a temperature within this range for at least 2 hours before the tests are made.

1. The rubber compound or other approved insulation must be sufficiently elastic to comply with a test made as follows:—

A sample of wire about 20 inches long shall have the braid and insulation removed for about 2 inches at each end, leaving the braid and insulation on balance of sample. One end of the bare copper should be fastened to a clamp on a shaft of the diameter given below, and a weight as given below attached to the other end of the bare copper wire. The shaft shall then be revolved ten times in ten seconds, wrapping the sample in a close wind around the shaft. With the tension left on the sample, it should then be immersed in water for 24 hours, immediately after which it should, while still immersed, be subjected to 1,500 volts alternating current for 1 minute.

	B. & S.	Mils.	Lbs.
Diam. of shaft	No. 14 wire	170	weight 10
Diam. of shaft	12 wire	190	weight 10
Diam. of shaft	10 wire	275	weight 12
Diam. of shaft	8 wire	375	weight 15

2. Any rubber compound used as insulation shall be tested for permanent set, elongation and tensile strength as follows:—

New wire.—A test piece taken from the wire, having insulation less than five sixty-fourths inch thick, shall have marks placed 2 inches apart, and shall be stretched longitudinally at the rate of 12 inches per minute till the marks are 5 inches apart, and then be immediately released and a measurement taken 30 seconds thereafter, when the distance between the marks must not exceed 2.5 inches. The test piece shall then be stretched until the marks are 6 inches apart before rupture. The tensile strength shall not be less than 400 lbs. per square inch, calculated upon the original cross section of the test piece before stretching.

Test pieces from wire having insulation five sixty-fourths inch thick or over shall be tested in a similar manner, but shall be stretched to 4 inches instead of 5 inches, and must not break until stretched 5 inches, and shall have a tensile strength of 400 lbs. per square inch.

Wire tested at any time up to one year from date of manufacture.—A test piece taken from wire having insulation less than five sixty-fourths inch thick shall have marks placed 2 inches apart, and shall be stretched longitudinally at the rate of 12 inches per minute till the marks are 4 inches apart, and then be immediately released and a measurement taken 30 seconds thereafter, when the distance between the marks must not exceed 2.5 inches.

Test pieces from wire having insulation five sixty-fourths inch or over shall be stretched to 3½ inches instead of 4 inches.

h. All of the above insulations must be protected by a substantial braided covering, properly saturated with a preservative compound. This covering must be sufficiently strong to withstand all the abrasions likely to be met with in practice, and must substantially conform to approved samples submitted by the manufacturer.

i. Five chemical tests shall be made of the rubber compound as follows: Acetone extract, alcoholic potash extract, chloroform extract, ash and total sulphur.

The sum total of the results of these five tests shall not exceed 80 per cent by weight of the total compound.

The ash test shall be supplemented by tests to determine the quantity of substances other than vulcanized rubber, which are combustible, but not soluble in acetone, alcoholic potash, or chloroform, and any such substance shall be counted as ash.

Tests to be made according to Underwriters' Laboratories specifications.

Lead Covered Wires and Cables for Interior Work Only. (Type letters R. S. L.)

j. The thickness of insulating wall of lead sheath rubber insulated conductors 0-600 volts to be the same as for braided cables, all cables to be covered with a compound filled tape or braid over the insulating wall. If braid is used, it shall be of such a thickness as to increase the required diameter over the insulating wall by at least one thirty-second of an inch, and must comply with the requirements for braid on braided conductors.

If tape is used it must not be less than one sixty-fourth of an inch thick and must lap at least one-fourth of its width. The width of the tape used should not exceed twice the square root of the diameter of the conductor over the insulating wall; *i. e.*, 500,000 C. M. three thirty-seconds rubber, tape not to exceed 2 inches in width; No. 14, three sixty-fourths rubber, tape should not exceed .8 inches in width.

The lead on single conductor cables, 0-600 volt class, sizes 2 B. & S. and smaller, both solid and stranded, to be not less than the thickness of rubber called for by Section *e*. On larger sizes the thickness of lead to be not less than the thickness of insulating wall called for, less one sixty-fourth of an inch; *i. e.*, thickness of lead on No. 2, one-sixteenth inch; on 1,000,000 C. M., three thirty-seconds inch. On multiple conductor cables, thickness of lead to be that called for by single conductor, having same diameter over the insulation as the multiple conductor cable has over the bunched insulated conductors.

Rubber insulated and lead sheathed cables, 601 to 7,000 volt classes inclusive (Type letters R. S. L—15, R. S. L—25, etc.) shall comply with Section *f*, and the lead sheath shall be the same as called for in 0-600 volt class, having same diameter under the lead as 601-7,000 volt conductor.

(Electrical test on finished leaded cables the same as on braided.)

It will be noted that the specifications governing the construction and testing of rubber covered wire have been greatly amplified and made much more rigid. The previous specifications allowed a wire of rather poor insulating quality and the statement has been made that "rubber covered wire," the insulating covering of which was entirely devoid of rubber, has been made to stand the tests.

The present specifications have been drawn up in such a manner as to demand a very good insulating covering for the wire, requiring a rubber compound with about 20% of rubber.

In the stretch test a ready method of roughly testing the wire in the field has been provided. To make this test remove the braid carefully and strip the entire rubber insulating covering from the wire. Place two marks two inches apart and test the wire by stretching it as directed. "New" wire is wire not over thirty days old and should stretch to five inches and back to two and one-half inches. Wire over thirty days old shall be stretched to 4 inches and should then return to two and one-half inches.

51. Slow-burning Weatherproof Wire. (Type Letters S. B. W.)

(See Figure 165.)

(For installation rules see No. 26 h.)

This wire is not as burnable as "weatherproof" nor as subject to softening under heat. It is not suitable for outside work.

a. The insulation must consist of two coatings, one to be fireproof in character and the other to be weatherproof. The

Figure 165.

fireproof coating must be on the outside and must comprise about six-tenths of the total thickness of the wall. The completed covering must be of a thickness not less than that given in the following table:—

B. & S. Gage.	Thickness.
14 to 8	3-64 inch.
7 to 2	1-16 inch.
1 to 0000	5-64 inch.
Circular Mils.	
250,000 to 500,000	3-32 inch.
500,000 to 1,000,000	7-64 inch.
Over 1,000,000	1-8 inch.

Measurements of insulating wall are to be made at the thinnest portion.

b. The fireproof coating shall be of the same kind as that required for "slow-burning wire," and must be finished with a hard, smooth surface.

c. The weatherproof coating shall consist of a stout braid, applied and treated as required for "weatherproof wire."

52. Slow-burning Wire. (Type Letters S. B.)

(For installation rules see No. 26 h.)

a. The insulation must consist of three braids of cotton or other thread, all the interstices of which must be filled with the fireproofing compound or with material having equivalent resisting and insulating properties. The outer braid must be specially designed to withstand abrasion, and its surface must be finished smooth and hard. The completed covering must be of a thickness not less than that given in the table under No. 51 *a.*

The solid constituent of the fireproofing compound must not be susceptible to moisture, and must not burn even when ground in an oxidizable oil, making a compound which, while proof against fire and moisture, at the same time has considerable elasticity, and which when dry will suffer no change at a temperature of 250 degrees Fahrenheit (121 degrees Centigrade), and which will not burn at even a higher temperature.

This is practically the old so-called "underwriters" insulation. It is especially useful in hot, dry places where ordinary insulations would perish, and where wires are bunched, as on the back of a large switchboard or in a wire tower, so that the accumulation of rubber insulation would result in an objectionably large mass of highly inflammable material.

53. Weatherproof Wire. (Type Letters W. R.)

(See Figure 166.)

(For rules for installation see No. 26 i and j.)

a. The insulating covering shall consist of at least three braids, all of which must be thoroughly saturated with a dense moisture-proof compound, applied in such a manner as to drive any atmospheric moisture from the cotton braiding, thereby securing a covering to a great degree waterproof and of high insulating power. This compound must not drip at 160 degrees Fahrenheit (71 degrees Centigrade). The thickness of insulation must not be less than that given in the table under No. 51 *a*, and the outer surface must be thoroughly slicked down.

This wire is for use outdoors, where moisture is certain and where fireproof qualities are not necessary.

54. Flexible Cord.

(For installation rules, see No. 32.)

Cords for pendant lamps and for portable use including Elevator, Lighting and Control Cables, and Theatre Stage and Border Cable (for Cords for Portable Heating Apparatus, see No. 54 d.)

a. Must be made of copper conductors, each built up from wires not larger than No. 26, or smaller than No. 36 B. & S. gage. Each conductor must have a carrying capacity not less than that of a No. 18 B. & S. gage wire, and must be covered

Figure 166.

by an approved insulation and protected from mechanical injury according to the following specifications for the several types of cord or cable. Each conductor must be covered with a tight close wind of fine cotton, or some other approved method must be employed to prevent a broken strand puncturing the insulation and to keep the rubber compound from corroding the copper, and must comply with No. 49.

b. The insulating covering on each conductor must be of a rubber compound, and must comply with No. 50 *c*, *g* and *i*, and must have a thickness of wall not less than that given in the following table:—

	Thickness, inches.	
B. & S. Gage.	Dry Places.	Damp Places.
18 and 16	1-32	3-64
14	3-64	3-64

For exception see *c*, 2.

Every completed single conductor shall be tested by passing it through a spring metal spiral not less than 6 inches long, so formed as to come in contact with all points on the circumference of the wire, while a voltage of not less than 500 volts for one sixty-fourth inch insulation, not less than 1,000 volts for one thirty-second inch insulation or not less than 1,500 volts for three sixty-fourths inch insulation is applied to the conductor and to the spiral.

The completed cord shall be subjected to a 1 minute test between conductors of 1,000 volts for one sixty-fourth inch insulation, 2,000 volts for one thirty-second inch insulation and 2,500 volts for three sixty-fourths inch insulation.

The insulating coverings in the above tests shall be sufficient to resist puncture or breakdown. The source of electromotive force shall be the same as that specified in No. 50 c.

c. Must have on outer protecting covering as follows:—

1. *For Pendant Lamps.*—(Type Letter C.) (See Figure 167.) In this class is to be included all flexible cord, which, under usual conditions, hangs freely in air, and which is not likely to be moved sufficiently to come in contact with surrounding objects.

It should be noted that pendant lamps provided with long cords, so that they can be carried about or hung over nails, or on machinery, etc., are not included in this class, even though they are usually allowed to hang freely in air.

Each conductor must have an approved braided covering so put on and sealed to place that when cut it will not fray out.

For use in damp places (Type Letters C. Wp.) the insulation must be at least three sixty-fourths of an inch thick

Figure 167.

and the braided coverings must either be thoroughly saturated with a moisture proof preservative compound or be enclosed in an outer braided moisture-proof preservative covering over the whole.

It will be specially noted that the thickness of rubber on cords for use in damp places must be not less than 3/64th of an inch. The object is to obtain a substantial thickness of rubber between wires of opposite polarity. "Portable" cord, "packing houses" cord, "brewery" cords and other cords of similar construction having only a 1/32d inch rubber insulation must not be used in damp places.

2. *For Portables.*—(Type Letter P.) (See Figure 168.) Flexible cord for portable use except in offices, dwellings or

Figure 168.

similar places, where cord is not liable to rough usage and where appearance is an essential feature, must meet all the requirements for flexible cord for pendants and in addition must have a tough, braided cover over the whole. There must also be an extra layer of rubber between the outer cover and the flexible cord.

For use in damp places (Type Letters P. Wp.) the insulation must be at least three sixty-fourths of an inch thick and

Figure 169.

the cord must have its outer covering saturated with a moisture-proof preservative compound thoroughly slicked down or must have a filler of approved material instead of the extra layer of rubber and have two outer braids saturated with a moisture-proof compound with the exterior surface thoroughly slicked down.

In offices, dwellings, or in similar places (Type Letters P. O.) (see Figure 169), where cord is not liable to rough usage and where appearance is an essential feature, flexible cord for portable use musf meet all of the requirements for flexible cord for "pendant lamps," both as to construction and thickness of insulation, and in addition must have a tough, braided cover over the whole, or providing there is an extra layer or rubber between the flexible cord and the outer cover, the insulation proper on each stranded conductor of cord may be of one sixty-fourth of an inch in thickness instead of as required for pendant cords.

Fexible cord for portable use may, instead of the outer coverings described above, have an approved metal, flexible armor. (Type Letters P. A.).

d. For Portable Heating Apparatus.—(Type Letter H.) (See Figure 170.) *Applies to all smoothing and sad irons and to any other heating device requiring over 250 watts. Must be made up as follows:—*

1. Conductors must comply with Section *a,* or may be of braided copper. If braided, each wire to be not larger than No. 30, or smaller than No. 36 B. & S. gage, except for con-

Figure 170.

ductors having a greater carrying capacity than No. 12 B. & S. gage when each wire may be as large as No. 28 B. & S. gage.

2. An insulating covering of rubber or other approved material not less than one sixty-fourth inch in thickness.

3. A braided covering not less than one thirty-second inch thick composed of long fibre absestos and having not over 10 per cent of carbon by weight.

4. An outer reinforcing covering not less than one sixty-fourth inch thick, especially designed to resist abrasion, must enclose either all the conductors as a whole or each conductor separately.

5. The completed cord shall be subjected to a 1 minute test between conductors of 1,500 volts, and must resist puncture or breakdown when so tested. The source of electromotive force to be the same as that specified in No. 50.

e. Theatre Stage Cable.—(Type Letter T.) (See Figure 171.) Shall consist of not more than three flexible copper conductors, each of a capacity not exceeding No. 4 B. & S. gage, each of which shall be built up of wires not larger than No. 26 B. & S. gage. Each conductor to have a tight close wind of cotton, or some other approved method must be employed to prevent a broken strand puncturing the insulation and to keep the rubber compound from corroding the copper. The insulation proper to be of rubber complying with No. 50 *b* and *d* and with requirements of No. 50 *c,* except that insulations less than three sixty-fourths of an inch in thickness (conductors having a capacity less than No. 14 B. & S. gage wire) must show an insulation resistance of not less than 50 megohms per mile during two weeks' immersion in water at 70 degrees Fahrenheit (21 degrees Centigrade), must have on each conductor an outer protective braided covering properly saturated with a preservative compound. The conductors to be twisted together, a filler of *approved* material being used

Figure 171.

to make cable round and to act as a cushion, and finished with two weatherproof braids over the whole.

The completed cable must be of such a flexible nature as to be readily handled, and when laid on the floor must align itself to the floor level.

f. Border Cables.—(Type Letter B.) (See Figure 172.) Shall consist of flexible copper conductors, each of which shall be built up of wires not larger than No. 26 B. & S. gage. Each conductor to have a tight close wind of cotton, or some other approved method must be employed to prevent a broken strand puncturing the insulation, and to keep the rubber compound from corroding the copper. The insulation proper to be of rubber complying with requirements of No. 50 *b, c* and *d,* must have on each conductor an outer protective braided covering properly saturated with a preservative compound. The conductors to be cabled together and finished with two weatherproof braids over the whole.

g. Elevator Lighting and Control Cables.—(Type Letter E.) Must comply with the requirements for threatre cable as regards insulation proper and the construction and covering of the individual conductors, except that none of these conductors shall be smaller than No. 14 B. & S. gage for elevator lighting cables, or No. 16 for elevator control cables. The outer covering shall consist either of three braids or of an extra layer of rubber and one or more outer braids. All braids must be properly treated with a preservative compound.

55. Fixture Wire.

(See Figure 173.)

(For installation rules, see Nos. 24 e, and 26 v to y. For construction of fixtures, see No. 77.)

a. Fixtures may be wired with approved flexible cord (see No. 54 *a* to *c*) or with approved rubber covered wire No. 14 B. & S. gage or larger (see No. 50).

In wiring certain designs of show-case fixtures, ceiling bulls-eyes and similar appliances in which the wiring is ex-

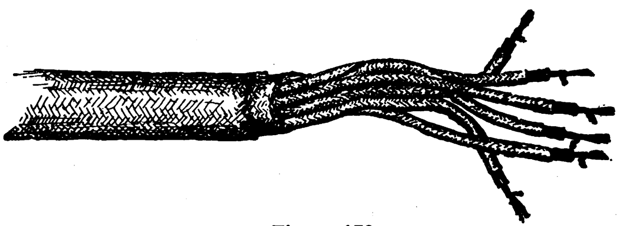


Figure 172.

posed to temperatures in excess of 120 degrees Fahrenheit (49 degrees Centigrade), from the heat of the lamps, slow-burning wire may be used (see No. 52). All such forms of fixtures must be submitted for examination, test and approval before being introduced for use.

For other wires for use in fixtures the following rules apply. (Type letters F-64 and F-32.)

b. May be made of solid or stranded conductors, with no strands smaller than No. 30 B. & S. gage, and must have a carrying capacity not less than that of a No. 18 B. & S. gage wire.

c. Solid conductors must be thoroughly tinned. If a stranded conductor is used, it must be covered by a tight, close wind of fine cotton, or some other approved method must be employed to prevent a broken strand puncturing the insulation and to keep the rubber compound from corroding the copper and must comply with the requirements of No. 49.

Figure 173.

d. The insulation on each conductor must consist of a rubber compound homogeneous in character, adhering to the conductor or to the separator, if one is used, and not less than one sixty-fourth inch in thickness for No. 18 B. & S. gage wire and not less than one thirty-second inch for No. 16 B. & S. gage.

e. Must be protected with a covering or braid at least one sixty-fourth inch in thickness, sufficiently tenacious to withstand the abrasion of being pulled into the fixture, and sufficiently elastic to permit the wire to be bent around a cylinder with twice the diameter of the wire without injury to the braid.

f. Must successfully withstand the tests specified in Nos. 50 *c*, *g* and *i*.

Sufficient data is not available for publication of values similar to those in No. 49 *d* and *e*, for voltage and resistance tests of insulations one sixty-fourth and one thirty-second inch thick, composed of rubber compounds required by present specifications on wires and suited for use in fixture wiring.

56. Conduit Wire. (Type Letters R. D.)

(For installation rules, see No. 26 n to p.)

a. Single wire for lined conduits must comply with the requirements of No. 50. (See Figure 174.) For unlined conduits it must comply with the same requirements (except that tape may be substituted for braid), and in addition there must be a second outer fibrous covering, at least one thirty-second of an inch in thickness for wires larger than No. 10 B. & S. gage, and at least one sixty-fourth of an inch in thickness for wires No. 10 B. & S. gage or less in size; this fibrous covering to be sufficiently tenacious to withstand abrasion of being hauled through the metal conduit. (Figures 175 and 176.)

b. For twin or duplex wires in lined conduit, each conductor must comply with the requirements of No. 50 (except that tape may be substituted for braid on the separate conductors), and must have a substantial braid covering the

Figure 174.

Figure 175.

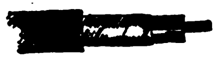


Figure 176.

whole. For unlined conduit each conductor must comply with requirements of No. 50 (except that tape may be substituted for braid), and in addition must have a braid covering the whole, at least one thirty-second of an inch in thickness and sufficiently tenacious to withstand the abrasion of being hauled through the metal conduit. (Figure 177.)

c. For concentric wire, the inner conductor must comply with the requirements of No. 50 (except that tape may be substituted for braid), and there must be outside of the outer conductor the same insulation as on the inner, the whole to be covered with a substantial braid, which for unlined conduits must be at least one thirty-second of an inch in thick-

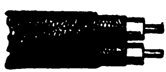


Figure 177.

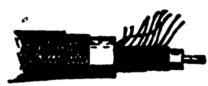


Figure 178.

ness, and sufficiently tenacious to withstand the abrasion of being hauled through the metal conduit. (Figure 178.)

d. The braids or tapes called for in sections *a*, *b* and *c*, must be properly saturated with a preservative compound.

The braid or tape required around each conductor in duplex, twin and concentric cables is to hold the rubber insulation in place and prevent jamming and flattening

57. Armored Cable. (Type Letters A. C.)
(See Figure 179.)

(For installation rules, see No. 27.)

a. The material, weight and form of armor must be such as to afford under conditions likely to be met in practice, pro-

Figure 179.

tection substantially equivalent in all respects to that afforded by unlined rigid conduit.

b. The conductors in same, single, or multiple, must have an insulating covering as required by No. 50. The whole bunch of conductors and fillers, if any, must have a separate exterior covering, and the filler, if any is used to secure a round exterior, must be impregnated with a moisture repellant.

58. Interior Conduits.

(For installation rules, see Nos. 26 n to p and 27.)

a. Each length of conduit, whether lined or unlined, must have the maker's name or initials stamped in the metal or attached thereto in a satisfactory manner, so that inspectors can readily see the same.

The use of paper stickers or tags cannot be considered satisfactory methods of marking, as they are readily loosened and lost off in the ordinary handling of the conduit.

Metal Conduits with Lining of Insulating Material.
(See Figure 180.)

b. The metal covering or pipe must be at least as strong as that specified in 58 *j*.

c. Must not be seriously affected externally by burning out a wire inside the tube when the iron pipe is connected to one side of the circuit.

d. Must have the insulating lining firmly secured to the pipe.

e. The insulating lining must not crack or break when a length of the conduit is uniformly bent at temperature of 212 degrees Fahrenheit (100 degree Centigrade), to an angle of 90 degrees, with a curve having a radius of fifteen inches, for pipes of one inch and less, and fifteen times the diameter of pipe for larger sizes.

f. The insulating lining must not soften injuriously at any temperature below 212 degrees Fahrenheit (100 degrees

Figure 180.

Centigrade) and must leave water in which it is boiled practically neutral.

g. The insulating lining must be at least one thirty-second of an inch in thickness. The materials of which it is composed must be of such a nature as will not have a deteriorating effect on the insulation of the conductor, and be sufficiently tough and tenacious to withstand the abrasion test of drawing long lengths of conductors in and out of same.

h. The insulating lining must not be mechanically weak after three days' submersion in water, and must not absorb more than ten per cent of its weight of water during 100 hours of submersion.

i. All elbows or bends must be so made that the conduit or lining of same will not be injured. The radius of the curve of the inner edge of any elbow must not be less than three and one-half inches.

Unlined Metal Conduits.

(See Figure 181.)

Rigid:—

j. Finished conduit to have weight per hundred feet not less than that given in the following table:—

Trade size Inches.	Approx. Internal Diameter Inches.	Min. Thickness of wall Inches.	Wt. per 100 ft. Pounds
½	.62	.100	75
¾	.82	.105	104
1	1.04	.125	152
1¼	1.38	.135	209
1½	1.61	.140	250
2	2.06	.150	350
2½	2.46	.200	535
3	3.06	.210	710

k. Pipe should be of sufficiently true circular section to admit of cutting true, clean threads, and should be very closely

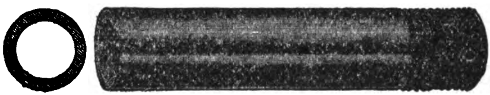


Figure 181.

the same in wall thickness at all points with clean square weld.

l. The pipe from which the conduit is made must be thoroughly cleaned to remove all scale and must then be protected against effects of oxidation, by baked enamel, zinc or other approved coating which will not soften at ordinary temperatures, and of sufficient weight and toughness to successfully withstand rough usage likely to be received during shipment and installation; and of sufficient elasticity to prevent flaking when one-half inch conduit is bent in a curve the inner edge of which has radius of 3½ inches. All conduit must have an interior coating of a character and appearance which will readily distinguish it from ordinary commercial pipe commonly used for other than electrical purposes.

m. All elbows or bends must be so made that the conduit will not be injured. The radius of the curve of the inner edge of any elbow not to be less than three and one-half inches.

Flexible:—

n. The material, weight and form of flexible metal conduits must be such as to afford under conditions likely to be met in practice, protection substantially equivalent in all respects to that afforded by rigid unlined metal conduits.

59. Outlet, Junction and Flush Switch Boxes.

(See Figure 182.)

(For installation rules see Nos. 27 and 28. For boxes for panel-boards, cut-outs and switches other than flush switches see No. 70.)

a. Must be of pressed steel having wall thickness not less than .078 inch (No. 14 U. S. metal gage), or of cast metal having wall thickness not less than one-eighth inch. Junction boxes of larger sizes must comply with requirements of No. 70, but must in all cases be of metal.

b. Must be well galvanized, enameled or otherwise properly coated, inside and out, to prevent oxidation.

It is recommended that the protective coating be of conductive material such as tin or zinc.

c. Must be so made that all openings not in use will be effectively closed by metal which will afford protection substantially equivalent to the walls of the box.

Fittings which are designed for bringing conductors from metal conduits to exposed wiring must be provided with non-absorptive, non-combustible, insulating bushings, which, except with flexible cord, must separately insulate each conductor.

d. Must be plainly marked, where it may readily be seen when installed, with the name or trademark of the manufacturer.

e. Must, in case of combination gas and electric outlets, be so arranged that connection with gas pipe at outlet may be made by means of an approved device.

Must be arranged to secure in position the conduit or flexible tubing protecting the wire.

This rule will be complied with if the conduit or tubing is firmly secured in position by means of some *approved* device which may or may not be a part of the box.

f. Boxes used with lined conduit must comply with the foregoing requirements, and in addition must have a tough and tenacious insulating lining at least one thirty-second inch thick, firmly secured in position.

g. Switch and outlet boxes must be so arranged that they can be securely fastened in place independently of the support afforded by the conduit piping, except that when entirely exposed, *approved* boxes, which are threaded so as to be firmly supported by screwing on to the conduit pipe, may be used.

Figure 182.

h. Switch boxes must completely enclose the switch on sides and back, and must provide a thoroughly substantial support for it. The retaining screws for the box must not be used to secure the switch in position.

i. Covers for outlet boxes if made of metal must be equal in thickness to that specified for the walls of the box, or must be of metal lined with an insulating material not less than one thirty-second inch in thickness, firmly and permanently secured to the metal. Covers may also be made of porcelain or other approved material, provided they are of such form and thickness as to afford suitable protection and strength.

60. Mouldings.

(For installation rules see Nos. 26 k to m.)

Wooden Mouldings

a. Must have, both outside and inside, at least two coats of waterproof material, or be impregnated with a moisture repellent.

b. Must be made in two pieces, a backing and a capping, and must afford suitable protection from abrasion. Must be so constructed as to thoroughly encase the wire, be provided with a tongue not less than one-half inch in thickness between the conductors, and have exterior walls which under grooves shall not be less than three-eighths inch in thickness, and on the sides not less than one-fourth inch in thickness.

It is suggested that only hard wood be used.

Metal Mouldings.

(See Figure 183.)

(For installation rules see Nos. 26 k to m and 29.)

c. Each length of such moulding must have maker's name or trade-mark stamped in the metal, or in some manner permanently attached thereto, in order that it may be readily identified in the field.

The use of paper stickers or tags cannot be considered satisfactory methods of marking, as they are readily loosened and lost off in ordinary handling of the moulding.

d. Must be constructed of iron or steel with backing at least .050 inch in thickness, and with capping not less than

Figure 183.

.040 inch in thickness, and so constructed that when in place the raceway will be entirely closed; must be thoroughly galvanized or coated with an approved rust preventive both inside and out to prevent oxidation.

e. Elbows, couplings and all other similar fittings must be constructed of at least the same thickness and quality of metal as the moulding itself, and so designed that they will both electrically and mechanically secure the different sections together and maintain the continuity of the raceway. The interior surfaces must be free from burrs or sharp corners which might cause abrasion of the wire coverings.

f. Must at all outlets be so arranged that the conductors cannot come in contact with the edges of the metal, either of capping or backing. Specially designed fittings which will interpose substantial barriers between conductors and the edges of metal are recommended.

g. When backing is secured in position by screws or bolts from the inside of the raceway, depressions must be provided to render the heads of the fastenings flush with the moulding.

h. Metal mouldings must be used for exposed work only and must be so constructed as to form an open raceway to be closed by the capping or cover after the wires are laid in.

61. Tubes and Bushings.

a. Construction.

(See Figure 184.)

Must be made straight and free from checks or rough projections, with ends smooth and rounded to facilitate the drawing in of the wire and prevent abrasion of its covering.

b. Material and Test.

Must be made of non-combustible, insulating material, which, when broken and submerged for 100 hours in pure

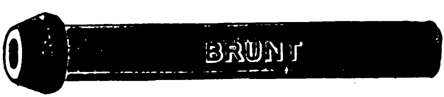


Figure 184.

water at 70 degrees Fahrenheit (21 degrees Centigrade), will not absorb over one-half of one per cent of its weight.

c. Marking.

Must have the name, initials or trade-mark of the manufacturer stamped in the ware.

d. Sizes.

Dimensions of wall and heads must be at least as great as those given in the following table:—

Diameter of Hole.	External Diameter.	Thickness of Wall.	External Diameter of Head.	Length of Head.
5/16 in.	9/16 in.	1/8 in.	13/16 in.	1/2 in.
3/8	11/16	5/32	15/16	1/2
1/2	13/16	5/32	1 3/16	1/2
5/8	15/16	5/32	1 5/16	1/2
3/4	1 3/16	7/32	1 11/16	5/8
1	1 7/16	7/32	1 15/16	5/8
1 1/4	1 13/16	9/32	2 5/16	5/8
1 1/2	2 3/16	11/32	2 11/16	3/4
1 3/4	2 9/16	13/32	3 1/16	3/4
2	2 15/16	15/32	3 7/16	3/4
2 1/4	3 5/16	17/32	3 13/16	1
2 1/2	3 11/16	19/32	4 3/16	1

An allowance of one sixty-fourth of an inch for variation in manufacturing will be permitted, except in the thickness of the wall.

62. Cleats.

a. Construction.

(See Figure 185.)

Must hold the wire firmly in place without injury to its covering.

Sharp edges which may cut the wire should be avoided.

b. Supports.

Bearing points on the surface must be made by ridges or rings about the holes for supporting screws, in order to avoid cracking and breaking when screwed tight.

c. Material and Test.

Must be made of non-combustible, insulating material, which, when broken and submerged for 100 hours in pure water at 70 degrees Fahrenheit (21 degrees Centigrade), will not absorb over one-half of one per cent of its weight.

d. **Marking.**

Must have the name, initials or trade-mark of the manufacturer stamped in the ware.

e. **Sizes.**

Must conform to the spacings given in the following table:—

Voltage.	Distance from Wire to Surface.	Distance between Wires.
0-300	½ inch	2½ inches

This rule will not be interpreted to forbid the placing of the neutral of a three-wire system in the center of a three-wire cleat where the difference of potential between the outside wires is not over 300 volts, provided the outside wires are separated two and one-half inches.

63. Flexible Tubing.

(See Figure 186.)

(For installation rules see No. 26 e. s and u.)

a. Must have a sufficiently smooth interior surface to allow the ready introduction of the wire.

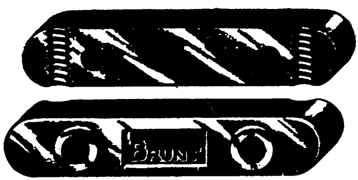


Figure 185.

b. Must be constructed of or treated with materials which will serve as moisture repellents.

c. The tube must be so designed that it will withstand all the abrasion likely to be met with in practice.

d. The linings, if any, must not be removable in lengths of over three feet.

e. The one-fourth inch tube must be so flexible that it will not crack or break when bent in a circle with six-inch radius at 50 degrees Fahrenheit (10 degrees Centigrade, and the covering must be thoroughly saturated with a dense moistureproof compound which will not slide at 150 degrees Fahrenheit (65 degrees Centigrade). Other sizes must be as well made.

f. Must not convey fire on the application of a flame from Bunsen burner to the exterior of the tube when held in a vertical position.

g. Must be sufficiently tough and tenacious to withstand severe tension without injury; the interior diameter must not

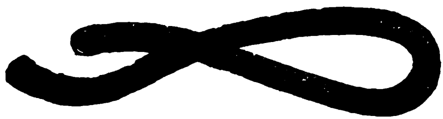


Figure 186.

be diminished or the tube opened up at any point by the application of a reasonable stretching force.

h. Must not close to prevent the insertion of the wire after the tube has been kinked or flattened and straightened out.

i. Must have a distinctive marking the entire length of the tube, so that tubing may be readily identified in the field.

64. Knobs.

a. Construction.

Split knobs must be constructed in two parts, a base and a cap, arranged to hold the wire firmly in place without injury to its covering. Sharp edges must be avoided. Solid knobs must be constructed with smooth groove, to contain wire.

b. Supports.

Bearing points on the surface wired over must be made by a ring or by ridges on the outside edge of the base, to provide for stability. At least one-fourth inch surface separation must be maintained between the supporting screw or nail and the conductor, and the knob must be so constructed that the supporting screw or nail cannot come in contact with the conductor. For wires larger than No. 4 B. & S. gage, split knobs (or single wire cleats) must be so constructed as to require the use of two supporting screws.

c. **Material and Test.**

Must be made of non-combustible, insulating material, which, when broken, and submerged for one hundred hours in pure water at 70 degrees Fahrenheit (21 degrees Centigrade) will not absorb one-half of one per cent of its weight.

d. **Marking.**

Must have the name, initials or trade-mark of the manufacturer stamped in the ware.

e. **Sizes.**

Must be so constructed as to separate the wire at least one inch from the surface wired over, and also conform to the following minimum dimensions:—

Size of Wire Inclusive.	Size of Base, Inches.			Solid Knobs, Groove. Inches.		Split Knobs, Thickness of Cap, Inches from Top of Wire Groove.
	Circular Knobs. Diameter.	Square Knobs or Single Wire Cleats.				
		Width.	Length.	Depth.	Diameter.	
14-1	1⅛	¾	1¾	3/16	¼	⅜
8-4	1½	⅞	2	5/16	5/16	⅝
2-00	2	1	2¼	7/16	⅝	⅝
000-300,000 C. M.	2½	1⅛	2¾	7/16	25/32	⅞
400,000-1,000,000 C. M.	3	1⅝	3¾	⅝	1¼	1

(For installation rules see Nos. 8 c, 19 20 b and 24.)

General Rules.

a. Must, when used for service switches, indicate, on inspection, whether the current be "on" or "off."

b. Must, for constant-current systems, close the main circuit and disconnect the branch wires when turned "off;" must be so construced that they shall be automatic in action, not stopping between points when started, and must prevent an arc between the points under all circumstances. They must indicate whether the current be "on" or "off."

Knife Switches.

(See Figure 187.)

Knife switches must be made to comply with the following Specifications, except in those few cases where peculiar design allows the switch to fulfill the general requirements in some other way, and where it can successfully withstand the test of Section *i*. In such cases the switch should be submitted for special examination before being used.

c. **Base.**

Must be mounted on non-combustible, non-absorptive, insulating bases. Other materials than slate, marble or porcelain must be submitted for special examination before being used. Bases with an area of over twenty-five square inches must have at least four supporting screws. Holes for the supporting screws must be so located or countersunk that there will be at least one-half of an inch space, measured over the surface, between the head of the screw or washer and the nearest live metal part, and in all cases when between parts of opposite polarity must be countersunk.

d. **Mounting.**

Pieces carrying the contact jaws and hinge clips must be secured to the base by at least two screws, or else made with a square shoulder, or provided with dowel-pins, to prevent possible turnings, and the nuts or screw-heads on the under side of the base must be countersunk not less than one-eighth inch and covered with a waterproof compound which will not melt below 150 degrees Fahrenheit (65 degrees Centigrade).

e. Hinges.

Hinges of knife switches must not be used to carry current unless they are equipped with spring washers, held by lock-nuts or pins, or their equivalent, so arranged that a firm and secure connection will be maintained at all positions of the switch blades.

Spring washers must be of sufficient strength to take up any wear in the hinge and maintain a good contact at all times.

f. Metal.

All switches must have ample metal for stiffness and to prevent rise in temperature of any part of over 50 degrees Fahrenheit (28 degrees Centigrade), at full load, the contacts being arranged so that a thoroughly good bearing at

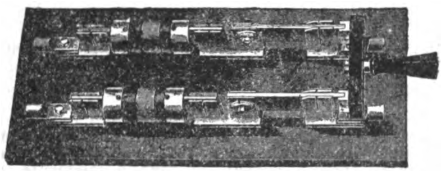


Figure 187.

every point is obtained with contact surfaces advised for pure copper blades of about one square inch for each seventy-five amperes; the whole device must be mechanically well made throughout.

g. Cross-Bars.

All cross-bars less than three inches in length must be made of insulating material. Bars of three inches and over, which are made of metal to insure greater mechanical strength, must be sufficiently separated from the jaws of the switch to prevent arcs following from the contacts to the bar on the opening of the switch under any circumstances. Metal bars should preferably be covered with insulating material.

To prevent possible turning or twisting the cross-bar must be secured to each blade by two screws, or the joints made with square shoulders or provided with dowel-pins.

h. Connections.

Switches for currents of over thirty amperes must be equipped with lugs, firmly screwed or bolted to the switch, and into which the conducting wires shall be soldered. For the smaller sized switches simple clamps can be employed, provided they are heavy enough to stand considerable hard usage.

Where lugs are not provided, a rugged double-V groove clamp is advised. A set screw gives a contact at only one point, is more likely to become loosened, and is almost sure to cut into the wire. For the smaller sizes, a screw and washer connection with upturned lugs on the switch terminal gives a satisfactory contact.

i. Test.

Must operate successfully at 50 per cent overload in amperes and 25 per cent excess voltage, under the most severe conditions with which they are liable to meet in practice.

This test is designed to give a reasonable margin between the ordinary rating of the switch and the breaking-down point, thus securing a switch which can always safely handle its normal load. Moreover, there is enough leeway so that a moderate amount of overloading would not injure the switch.

j. Marking.

Must be plainly marked where it will be visible, when the switch is installed, with the name of the maker and the current and the voltage for which the switch is designed.

Triple pole switches designed with 125 volt spacings, between adjacent blades, should be marked 125 volts, and may be used on D. C. 3-wire systems having 125 volts between adjacent wires and 250 volts between the two outside wires.

k. Spacings.

Spacings must be at least as great as those given in the following table:—

Not over 125 volts D. C. and A. C.

For Switchboards and Panel Boards:—

	Minimum separation of nearest metal parts of opposite polarity.	Minimum break-distance.
10 amperes	¾ inch	½ inch
30 amperes	1 inch	¾ inch
60 amperes	1¼ inch	1 inch

The 10-ampere switch must have ample metal for stiffness, and to prevent rise in temperature of any part of more than 50 degrees Fahrenheit (28 degrees Centigrade) when carrying 30 amperes, the contacts being arranged so that a thoroughly good bearing at every point is obtained with contact surface advised for pure copper blades of about 0.4 square inch.

Not over 125 volts D. C. and A. C.

For Individual Switches:—

30 amperes	1¼ inch	1 inch
60 and 100 amperes	1½ inch	1¼ inch
200 and 300 amperes	2¼ inch	2 inch
400 and 600 amperes	2¾ inch	2½ inch
800 and 1,000 amperes	3 inch	2¾ inch

The 300-ampere switch must not be equipped with cut-out terminals.

250 volts only D. C. and A. C.

For all switches.

30 amperes	1¾ inch	1½ inch

Not over 250 volts D. C.
nor over 500 volts A. C.

For all switches:—

30, 60 and 100 amperes	2¼ inch	2 inch
200 and 300 amperes	2½ inch	2¼ inch
400 and 600 amperes	2¾ inch	2½ inch
800 and 1,000 amperes	3 inch	2¾ inch

The above switches must be stamped "250 V. D. C., 500 V. A. C"

The 30-ampere switch must have ample metal to prevent rise in temperature of any part of more than 50 degrees Fahrenheit (28 degrees Centigrade) when carrying 60 amperes, the contacts being arranged so that a thoroughly good bearing at every point is obtained with contact surfaces advised for pure copper blades of about 0.8 square inch.

The 300-ampere switch must not be equipped with cut-out terminals.

Cut-out terminals on switches for over 250 volts must be designed and spaced for 600 volt fuses, and in such cases the switches must be stamped "500 V. A. C."

Not over 600 volts D. C. and A. C.

For all switches:—

30 and 60 amperes	4 inch	3½ inch
100 amperes	4½ inch	4 inch

The 30-ampere switch must have ample metal to prevent rise in temperature of any part of more than 50 degrees Fahrenheit (28 degrees Centigrade) when carrying 60 amperes, the contacts being arranged so that a thoroughly good bearing at every point is obtained with contact surfaces advised for pure copper blades of about 0.8 square inch.

Auxiliary breaks or the equivalent are recommended for D. C. switches designed for over 250 volts, and must be provided on D. C. switches designed for use in breaking currents greater than 100 amperes at a voltage of over 250.

For three-wire direct current and three-wire single phase systems the separations and break distances for plain three-pole knife switches must not be less than those required in the above table for switches designed for the voltage between the neutral and outside wires.

Snap Switches.

(See Figures 188 and 189.)

Flush, push-button, door, fixture and other snap switches used on constant-potential systems, must be constructed in accordance with the following specifications.

l. Base.

Current-carrying parts must be mounted on non-combustible, non-absorptive, insulating bases, such as slate or porcelain, and the holes for supporting screws should be countersunk not less than one-eighth of an inch. There must in no case be less than three sixty-fourths of an inch space between supporting screws and current-carrying parts.

Sub-bases of non-combustible, non-absorptive, insulating material, which will separate the wires at least one-half of

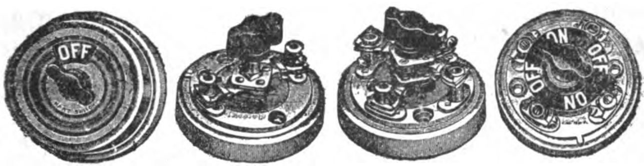


Figure 188.

an inch from the surface wired over, must be furnished with all snap switches used in exposed or moulding work.

m. Mounting.

Pieces carrying contact jaws must be secured to the base by at least two screws, or else made with a square shoulder, or provided with dowel-pins or otherwise arranged, to prevent possible turnings; and the nuts or screw heads on the under side of the base must be countersunk not less than one-eighth inch, and covered with a waterproof compound which will not melt below 150 degrees Fahrenheit (65 degree Centigrade).

n. Metal.

All switches must have ample metal for stiffness and to prevent rise in temperature of any part of over 50 degrees Fahrenheit (28 degrees Centigrade) at full load. The whole device must be mechanically well made throughout.

o. Insulating Material.

Any material used for insulating current-carrying parts must retain its insulating and mechanical strength when subject to continued use, and must not soften at a temperature of 212 degrees Fahrenheit (100 degrees Centigrade).

p. Binding Posts.

Binding posts must be substantially made, and the screws must be of such size that the threads will not strip when set up tight.

A set-screw is likely to become loosened, and is almost sure to cut into the wire. A binding screw under the head of which the wire may be clamped and a terminal plate provided with upturned lugs or some other equivalent arrangement, afford reliable contact. Switches with the set-screw form of contact will not be approved.

q. Covers.

Covers made of conducting material, except face plates for flush switches. must be lined on sides and top with insulat-

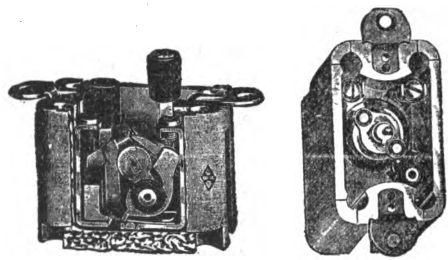


Figure 189.

ing, tough and tenacious material at least one thirty-second inch in thickness, firmly secured so that it will not fall out with ordinary handling. The side lining must extend slightly beyond the lower edge of the cover.

r. Handle or Button.

The handle or button or any exposed parts must not be in electrical connection with the circuit.

s. Test.

Must "make" and "break" with a quick snap, and must not stop when motion has once been imparted by the button or handle.

Snap switches of the spring break pattern, normally complying with the above requirements, but with movement of the contact carrier under control of the operator at any point in the operation of the device, must be considered in a class with switches of the regular knife blade pattern and conform to the specifications of Section *k*.

Must operate successfully at 50 per cent overload in amperes and at 125 volt direct current, for all 125 volt or less switches, and at 250 volts direct current, for all 126 to 250 volt switches under the most severe conditions which they are liable to meet in practice. For switches rated higher than ten amperes, this test shall be at 25 per cent overload instead of 50 per cent.

When slowly turned "on" and "off" at a rate not to exceed ten times per minute, while carrying the rated current at rated voltage, must "make" and "break" the circuit six thousand times before failing.

t. Marking.

Must be plainly marked, where it may be readily seen after the device is installed, with the name or trade-mark of the maker and the current and voltage for which the switch is designed.

On flush switches these markings may be placed on the subplate. On other types they must be placed on the *front* of the cap, cover or plate.

Switches which indicate whether the current is "on" or "off" are recommended.

66. Circuit Breakers.

(See Figure 190.)

(For installation rules see Nos. 8 c, 19, 23 e and f.)

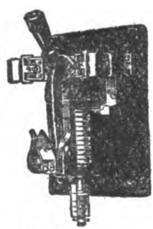
Circuit Breakers for operation on circuits of 550 volts or less must be made to comply with the following specifications, except in those few cases where peculiar design allows the breaker to fulfill the general requirements in some other way, and where it can successfully withstand the test of Section d. In such cases the breakers should be submitted for special examination and approval before being used.

a. Base.

Must be mounted on non-combustible, non-absorptive, insulating bases, such as slate or marble. Bases with an area of over twenty-five square inches must have at least four supporting screws. Holes for the supporting screws must be so located or countersunk that there will be at least one-half of an inch space measured over the surface between the head of the screw or washer and the nearest live metal part, and in all cases when between parts of opposite polarity must be countersunk.

b. Mounting.

Pieces carrying contact parts must be screwed to the base by at least two screws, or else made with a square shoulder, dowel pin, or equivalent device, to prevent possible turning, and the nuts or screw heads on the under side of the base of "front connected" breakers must be countersunk not less than


Single Pole.


Double Pole.

Figure 190.

one-eighth inch, and covered with a waterproof compound which will not melt below 150 degrees Fahrenheit (65 degrees Centigrade). All breakers must be provided with easily accessible means of tripping them by hand without injury to the operator.

c. **Breaking Capacity.**

Must successfully operate three times with two minute intervals intervening without incapacitating the breaker, the conditions of testing current to be as given in the following table:—

Current rating of breakers.	Per cent of Voltage drop in test circuit with rated current flowing.	Minimum available capacity of supply system not including overload capacity.
0 to 100 Amp.	2	1,000 Amp.
101 to 300 Amp.	3	3,000 Amp.
400 Amp.	4	4,000 Amp.
500 Amp.	5	5,000 Amp.

No filing of contacts or other repairing of the breaker to be made during the test.

Multiple breakers must comply with above requirements whether the test is on all poles at once or on one pole individually.

d. **Voltage Test.**

Must successfully withstand 2,000 volts A. C. for one minute between live metal and ground, between poles in multipolar breaker, and between terminals with breaker open.

e. **Carrying Capacity.**

The maximum rise in temperature at rated current must not exceed 50 degrees Centigrade (90 degree Fahrenheit) for coils, or 30 degrees Centigrade (54 degrees Fahrenheit) for other parts.

f. **Calibration.**

Must not have a plus or minus error greater than 10 per cent at any point of its calibration.

g. **Mechanism.**

Metal work of automatic over load circuit breakers must be substantial in construction, and must have ample metal for stiffness. The contact parts shall be arranged so that theroughly good bearings are obtained; the entire device must be mechanically well made throughout.

h. **Marking.**

Must be plainly marked, where it will be visible when installed, with the name of the maker and the current and voltage for which the device is designed.

67. Cut-Outs.

(For installation rules see Nos. 8 c, 19, 23, 25 a and 33 a.)

These requirements do not apply to rosettes, attachment plugs, car lighting cut-outs, and protective devices for signaling systems.

General Rules.

a. Must be supported on bases of non-combustible, non-absorptive, insulating material.

b. Cut-outs must be of the enclosed type, when not arranged in *approved* cabinets, so as to obviate any danger of the melted fuse metal coming in contact with any substance which might be ignited thereby.

c. Cut-outs must operate successfully on short-circuits, under the most severe conditions with which they are liable to meet in practice, at 25 per cent above their rated voltage, and for link fuse cut-outs with fuses rated at 50 per cent above the current for which the cut-out is designed, and for enclosed fuse cut-outs with the largest fuses for which the cut-out is designed.

With link fuse cut-outs there is always the possibility of a larger fuse being put into the cut-out than it was designed for, which is not true of enclosed fuse cut-outs classified as required under Section *o*. Again the voltage in most plants can, under some conditions, rise considerably above the normal. The need of some margin as a factor of safety to prevent the cut-outs from being ruined in ordinary service, is therefore evident.

The most severe service which can be required of a cut-out in practice is to open a "dead short-circuit," with only one fuse blowing, and it is with these conditions that all tests should be made. (See Section i.)

d. Must be marked where it will be plainly visible when installed with the name of the maker, and current and voltage for which the device is designed.

Link-Fuse Cut-Outs.

(Cut-outs of porcelain are not approved for link fuses.)

The following rules are intended to cover open link fuses mounted on slate or marble bases, including switchboards, tablet-boards and single fuse-blocks. They do not apply to fuses mounted on porcelain bases, to the ordinary porcelain cut-out blocks, enclosed fuses, or any special or covered type of fuse. When tablet-boards or single fuse-blocks with such open link fuses on them are used in general wiring, they must be enclosed in cabinet boxes made to meet the requirements of No. 70. This is necessary, because a severe flash may occur when such fuses melt, so that they would be dangerous if exposed in the neighborhood of any combustible material.

e. Base.

(See Figures 191 and 192.)

Must be mounted on slate or marble bases. Bases with an area of over twenty-five square inches must have at least four supporting screws. Holes for supporting screws must

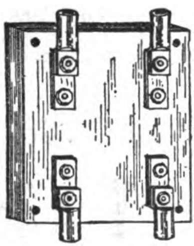


Figure 191.

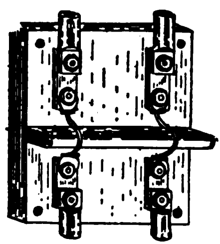


Figure 192.

be kept outside of the area included by the outside edges of the fuse-block terminals, and must be so located or countersunk that there will be at least one-half of an inch space, measured over the surface, between the head of the screw or washer and the nearest live metal part.

f. Mounting.

Nuts or screw heads on the under side of the base must be countersunk not less than one-eighth inch, and covered with a waterproof compound which will not melt below 150 degrees Fahrenheit (65 degrees Centigrade).

g. **Metal.**

All fuse-block terminals must have ample metal for stiffness and to prevent rise in temperature of any part of over 50 degrees Fahrenheit (28 degrees Centigrade) at full load. Terminals, as far as practicable, should be made of compact form instead of being rolled out in thin strips, and sharp edges or thin projecting pieces, as on wing thumb nuts and the like, should be avoided. Thin metal, sharp edges and projecting pieces are much more likely to cause an arc to start than a more solid mass of metal. It is a good plan to round all corners of the terminals and to chamfer the edges.

h. **Connections.**

Clamps for connecting the wires to the fuse-block terminals must be of solid, rugged construction, so as to insure a thoroughly good connection and to withstand considerable hard usage. For fuses rated at over thirty amperes, lugs firmly screwed or bolted to the terminals and into which the conducting wires are soldered must be used.

See note under No. 65 h.

i. **Test.**

Must operate successfully when blowing only one fuse at a time on short-circuits with fuses rated at 50 per cent above and with a voltage 25 per cent above the current and voltage for which the cut-out is designed.

j. **Spacings.**

Spacings must be at least as great as those given in the following table, which applies only to plain, open link-fuses mounted on slate or marble bases. The spaces given are correct for fuse-blocks to be used on direct-current systems, and can therefore be safely followed in devices designed for alternating currents. If the copper fuse-tips overhang the edges of the fuse-block terminals, the spacings should be measured between the nearest edges of the tips

	Minimum Separation of Nearest Metal Parts of Opposite Polarity.	Minimum Break-Distance.
Not over 125 Volts:		
10 amperes or less	¾ inch	¾ inch
11- 100 amperes	1 inch	¾ inch
101- 300 amperes	1 inch	1 inch
301-1,000 amperes	1¼ inch	1¼ inch
Not over 250 Volts:		
10 amperes or less	1½ inch	1¼ inch
11- 100 amperes	1¾ inch	1¼ inch
101- 300 amperes	2 inch	1½ inch
301-1,000 amperes	2½ inch	2 inch

A space must be maintained between fuse terminals of the *same polarity* of at least one-half inch for voltages up to 125 and of at least three-quarter inch for voltages from 126 to 250. This is the minimum distance allowable, and greater separation should be provided when practicable.

For 250 volt boards or blocks with the ordinary front-connected terminals, except where these have a mass of compact form, equivalent to the back-connected terminals usually found in switchboard work, a substantial barrier of insulating material not less than one-eighth of an inch in thickness, must be placed in the "break" gap—this barrier to extend out from the base at least one-eighth of an inch farther than any bare live part of the fuse-block terminal, including binding screws, nuts and the like.

For three-wire systems cut-outs must have the break-distance required for circuits of the potential of the outside wires.

Enclosed-Fuse Cut-Outs—Plug and Cartridge Type.

k. Base.

(See Figure 193.)

Must be made of non-combustible, non-absorptive, insulating material. Blocks with an area of over twenty-five square inches must have at least four supporting screws. Holes for supporting screws must be so located or countersunk that there will be at least one-half of an inch space, measured over the surface, between the screw-head or washer and the nearest live metal part, and in all cases when between parts of opposite polarity must be countersunk.

l. **Mounting.**

Nuts or screw-heads on the under side of the base must be countersunk at least one-eighth of an inch and covered with a waterproof compound which will not melt below 150 degrees Fahrenheit (65 degrees Centigrade).

m. **Terminals.**

Except for sealable service and meter cut-outs, terminals must be of either the Edison plug, spring clip or knife blade type, of *approved* design, to take the corresponding standard

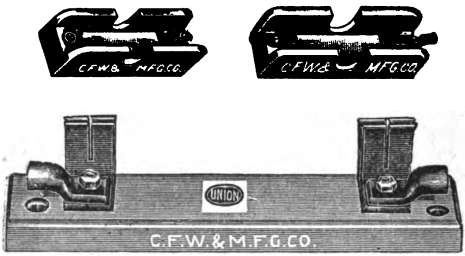


Figure 193.

enclosed fuses. They must be secured to the base by two screws or the equivalent, so as to prevent them from turning, and must be so made as to secure a thoroughly good contact with the fuse. End stops must be provided to insure the proper location of the cartridge fuse in the cut-out.

n. **Connections.**

Clamps for connecting wires to the terminals must be of a design which will insure a thoroughly good connection, and must be sufficiently strong and heavy to withstand considerable hard usage. For fuses rated to carry over thirty amperes, lugs firmly screwed or bolted to the terminals and into which the connecting wires shall be soldered must be used.

o. **Classification.**

Must be classified as regards both current and voltage as given in the following table, and must be so designed that the bases of one class cannot be used with fuses of another class rated for a higher current or voltage.

Standard Plug or Cartridge Cut-Outs.

Not over 250 Volts:	*Not over 600 Volts:*
0- 30 amperes.	0- 30 amperes.
31- 60 amperes.	31- 60 amperes.
61-100 amperes.	61-100 amperes.
101-200 amperes.	101-200 amperes.
201-400 amperes.	201-400 amperes.
401-600 amperes.	

Sealable Service and Meter Cut-Outs.

Not over 250 Volts:	*Not over 600 Volts:*
0- 30 amperes.	0- 30 amperes.
31- 60 amperes.	31- 60 amperes.
61-100 amperes.	61-100 amperes.
101-200 amperes.	101-200 amperes.

p. **Design.**

Must be of such a design that it will not be easy to form accidental short circuits across live metal parts of opposite polarity on the block or on the fuses in the block.

68. Fuses.

(For installation rules, see Nos. 19 and 23.)

Link Fuses.

(See Figure 194.)

a. **Terminals.**

Must have contact surfaces or tips of harder metal, having perfect electrical connections with the fusible part of the strip.

The use of the hard metal tip is to afford a strong mechanical bearing for the screws, clamps or other devices provided for holding the fuse.

b. **Rating.**

Must be stamped with about 80 per cent of the maximum current which they can carry indefinitely, thus allowing about 25 per cent overload before the fuse melts.

With naked open fuses, of ordinary shapes and with not over 500 amperes capacity, the *minimum* current which will melt them in about five minutes may be safely taken as the melting point, as the fuse practically reaches its maximum temperature in this time. With larger fuses a longer time is necessary. This data is given to facilitate testing.

c. **Marking.**

Fuse terminals must be stamped with the maker's name or initials, or with some known trade-mark.

Enclosed Fuses—Plug and Cartridge Type.

These requirements do not apply to fuses for rosettes, attachment plugs, car-lighting cut-outs and protective devices for signaling systems.

d. **Construction.**

The fuse casing must be sufficiently dust-tight so that lint

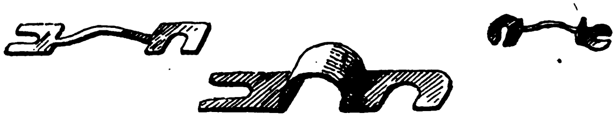


Figure 194.

and dust cannot collect around the fusible wire and become ignited when the fuse is blown.

The fusible wire must be attached to the terminals in such a way as to secure a thoroughly good connection and to make it difficult for it to be replaced when melted.

e. **Classification.**

Must be classified to correspond with the different classes of cut-out blocks, and must be so designed that it will be impossible to put any fuse of a given class into a cut-out block which is designed for a current or voltage lower than that of the class to which the fuse belongs.

f. Terminals.

The fuse terminals must be sufficiently heavy to insure mechanical strength and rigidity. The styles of terminals, except for use in sealable service and meter cut-outs, must be as follows:—

Not over 250 Volts:

0-30 Amps.	*A*. Cartridge fuse (ferrule contact). *B*. Approved plugs for Edison cut-outs not exceeding 125 volts, but including 3-wire circuits with grounded neutral and 250 volts between outside wires.
31-60 Amps.	Cartridge fuse (ferrule contact).
61-100 Amps. 101-200 Amps. 201-400 Amps. 401-600 Amps.	Cartridge fuse (knife blade contact).

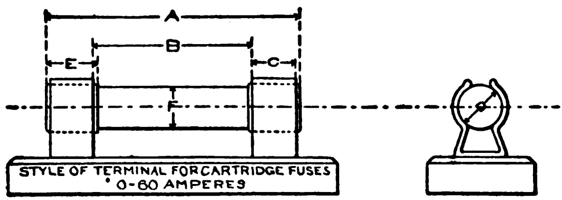
Not over 600 Volts:

0-30 Amps. 31-60 Amps.	Cartridge fuse (ferrule contact).
61-100 Amps. 101-200 Amps. 201-400 Amps.	Cartridge fuse (knife blade contact).

g. Dimensions.

Cartridge enclosed fuses and corresponding cut-out blocks, except for sealable service and meter cut-outs, must conform to the dimensions given in the table attached.

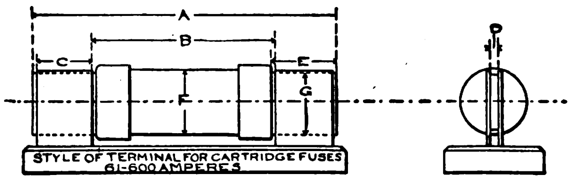
TABLE OF DIMENSIONS OF THE STANDARD CARTRIDGE



Form 1. CARTRIDGE FUSE—Ferrule Contact.

Voltage.	Rated Capacity. Amperes.		A Length over Terminals. Inches.	B Distance between Contact Clips Inches.	C Width of Contact Clips. Inches.
Not over 250	0-30	Form 1	2	1	½
	31-60		3	1¾	⅝
	61-100	Form 2	5⅞	4	⅞
	101-200		7⅛	4½	1¼
	201-400		8⅝	5	1¾
	401-600		10⅜	6	2⅛
Not over 600	0-30	Form 1	5	4	½
	31-60		5½	4¼	⅝
	61-100	Form 2	7⅞	6	⅞
	101-200		9⅝	7	1¼
	201-400		11⅝	8	1¾

NATIONAL ELECTRICAL CODE
ENCLOSED FUSE



Form 2. CARTRIDGE FUSE—Knife Blade Contact.

D	E	F	G		
Diameter of Ferrules or Thickness of Terminal Blades. Inches.	**Min. Length of Ferrules or of Terminal Blades** outside of Tube. Inches	**Dia. of** Tube. Inches.	**Width of Terminal** Blades. Inches.		**Rated Capacity.** **Amperes.**
9/16 13/16	½ ⅝	½ ¾		Form 1	0-30 31-60
⅛ 3/16 ¼ ¼	1 1⅜ 1⅞ 2¼	1 1½ 2 2½	¾ 1⅛ 1⅝ 2	Form 2	61-100 101-200 201-400 401-600
13/16 1 1/16	½ ⅝	¾ 1		Form 1	0-30 31-60
⅛ 3/16 ¼	1 1⅜ 1⅞	1¼ 1¾ 2½	¾ 1⅛ 1⅝	Form 2	61-100 101-200 201-400

h. Rating.

Fuses must be so constructed that with the surrounding atmosphere at a temperature of 75 degrees Fahrenheit (24 degrees Centigrade) they will carry indefinitely a current 10 per cent greater than that at which they are rated, and at a current 25 per cent greater than the rating, they will open the circuit without reaching a temperature which will injure the fuse tube or terminals of the fuse block. With a current 50 per cent greater than the rating and at room temperature of 75 degrees Fahrenheit (24 degrees Centigrade), the fuses starting cold, must blow within the time specified below:—

0-30 Amperes	1 minute
31-60 Amperes	2 minutes
61-100 Amperes	4 minutes
101-200 Amperes	6 minutes
201-400 Amperes	12 minutes
401-600 Amperes	15 minutes

i. Marking.

Must be marked, where it will be plainly visible, with the name or trade-mark of the maker, the voltage and current for which the fuse is designed, and the words "National Electrical Code Standard." Each fuse must have a label, the color of which must be green for 250-volt fuses and red for 600-volt fuses.

It will be satisfactory to abbreviate the above designation to "N. E. Code St'd" where space is necessarily limited.

j. Temperature Rise.

The temperature of the exterior of the fuse enclosure must not rise more than 125 degrees Fahrenheit (70 degrees Centigrade) above that of the surrounding air when the fuse is carrying the current for which it is rated.

k. Test.

Must not hold an arc or throw out melted metal or sufficient flame to ignite easily inflammable material on or near the cut-out when only one fuse is blown at a time on a short circuit on a system of the voltage for which the fuse is rated.

The normal capacity of the system must be in excess of the load on it just previous to the test by at least five times the rated capacity of the fuse under test.

The resistance of the circuit up to the cut-out terminals

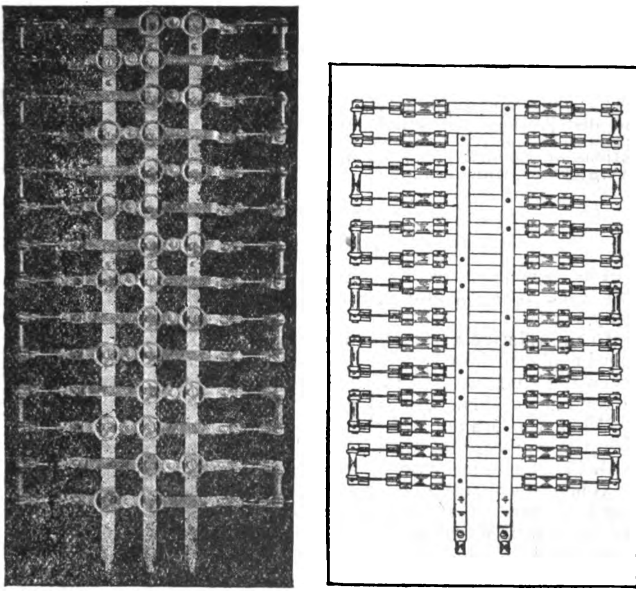


Figure 195.

must be such that the impressed voltage at the terminals will be decreased one per cent when a current of 100 amperes is passed between them.

For convenience a current of different value may be used, in which case the per cent drop in voltage allowable would vary in direct proportion to the difference in current used.

The above requirement regarding the capacity of the testing circuit is to guard against making the test on a system of so small capacity that the conditions would be sufficiently favorable to allow really poor fuses to stand the test acceptably. On the other hand, it must be remembered that if the test is made on a system of very large capacity, and especially if there is but little resistance between the generators and fuse, the conditions may be more severe than are liable to be met with in practice outside of the large power stations, the result being that fuses entirely safe for general use may be rejected if such test is insisted upon.

69. Tablet and Panel Boards.

The following specifications are intended to apply to all panel and distributing boards used for the control of light and power circuits, but not to such switch boards in central stations, substations or isolated plants as directly control energy derived from generators or transforming devices.

(See Figure 195.)

a. Design.

The specifications for construction of switches and cutouts (see Nos. 65 and 67) must be followed as far as they apply.

In the relative arrangement of fuses and switches, the fuses may be placed between the bus-bars and the switches, or between the switches and the circuits, except in the case of service switches, when Rule 23 *a* must be complied with.

When the branch switches are between the fuses and busbars, the connections must be so arranged that the blades will be dead when the switches are open.

When there are exposed live metal parts on the back of board, a space of at least one-half inch must be provided between such live metal parts and the cabinet in which board is mounted.

b. Spacings.

The following minimum distance between bare live metal parts (bus-bars, etc.) must be maintained:—

	Between parts of opposite polarity, except at switches and link fuses. When mounted on the same surface.	When held free in air.	Between parts of same polarity. At link fuses.
Not over 125 volts,	¾ inch.	½ inch.	½ inch.
Not over 250 volts,	1¼ inch.	¾ inch.	¾ inch.
Not over 600 volts,	2 inch.	1¾ inch.	

At switches or enclosed fuses, parts of the same polarity may be placed as close together as convenience in handling will allow.

It should be noted that the above distances are the minimum allowable, and it is urged that greater distances be adopted wherever the conditions will permit.

The spacings given in the first column apply to the branch conductors where enclosed fuses are used. Where link fuses or knife switches are used, the spacings must be at least as great as those required by Nos. 65 and 67.

The spacings given in the second column apply to the distance between the raised main bars and between these bars and the branch bars over which they pass.

The spacings given in the third column are intended to prevent the melting of a link fuse by the blowing of an adjacent fuse of the same polarity.

Panel boards of special design in which the insulation and separation between bus-bars and between other current-carrying parts is secured by means of barriers or insulating materials instead of by the spacings given above, must be submitted for special examination and approval before being used.

c. Marking.

Must be marked where the marking can be plainly seen when installed, with the name or trade-mark of the manufacturer and the maximum capacity in amperes and the voltage for which the board is designed.

Figure 196 shows a view of the McWilliams "Simplicity" type Metering Panelboard, manufactured by the J. Lang Electric Co., Chicago, with six circuits.

Figure 197 shows the same type of panelboard diagrammatically, with twenty circuits.

This panelboard is designed for use in office, factory, store and apartment buildings where there are tenants requiring metered service.

This panelboard is also used in manufacturing buildings where individual costs are required on the current consumed for different departments.

The greater number of these panelboards are used in office buildings, owing to the fact that a large number of meters and the consequent wiring and maintenance of same is eliminated. By the use of this panelboard but one meter is required for each tenant irrespective of the number or combination of rooms occupied. With this panelboard the meters are grouped at one location in a central meter closet adjacent to the panelboard. It is now customary to run circuit wiring from this

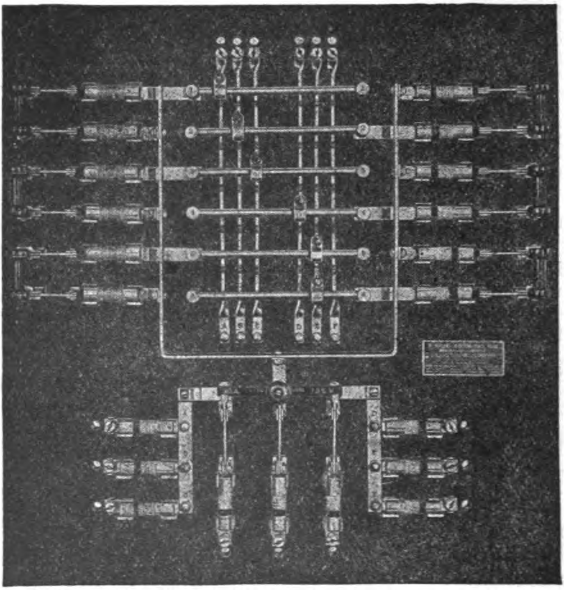


Figure 196.

central point of distribution so that one circuit operates to each room on the floor, or to each bay, if the building is of factory type.

By the use of this panelboard with wiring of this character one or all of the circuits can be connected together through one meter.

The panelboard shown in Figure 196 is designed for six meters, while the panelboard shown in Figure 197 is designed for twelve meters. The meter loops are fused on one polarity for the 2-wire meter, and on both polarities for the 3-wire type meter. The common neutral or pressure wire loops from meter to meter, without fusing.

The 2-wire branch circuits are protected in the usual manner by two fuses. One main bus bar runs the full length of the panelboard adjacent to the fuse plug holders on either side of the board. To this bus bar one set of fuses are connected. The other, or adjacent set of fuses are connected to the numbered posts which, in turn, support the round circuit bars crossing the meter bars. The round circuit bar which crosses the meter bar contains a movable switch contactor. This movable switch contactor can be electrically connected to the meter bars at every point the round circuit bar crosses the meter bars. This permits the grouping of circuits in any combination to selected meter bars and through the desired meter.

The meter bus bars are placed on edge for the purpose of condensing the panelboard as much as possible, and also for the purpose of providing a switch blade surface for the movable contactor to engage with.

The meter bars are carried to proper terminal lugs at the top of the board for meter loop connections.

By carefully tracing out the circuit connections in Figure 197 it will be noted that circuits 1, 2 and 3 which operate to rooms 1, 2 and 11 are connected to meter "B."

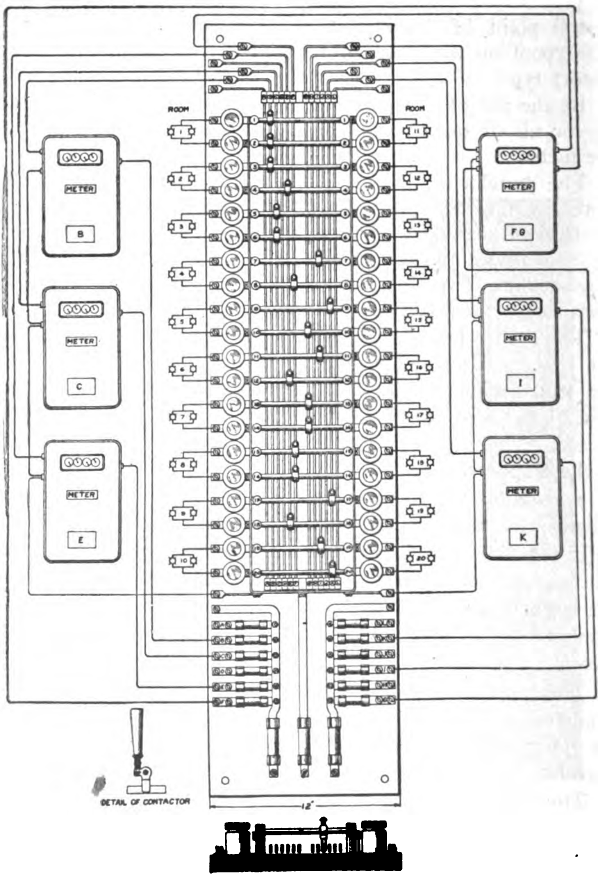

ROOM
ROOM
METER
B
METER
C
METER
E
METER
FG
METER
I
METER
K
DETAIL OF CONTACTOR
12"

Figure 197.

Circuits 5 and 6 operating to rooms 3 and 13 are connected to meter "C."

Circuits 4, 12 and 18 operating to rooms 12, 16 and 19 are connected to meter "E."

The preceding three meters are of the 2-wire type.

Circuits 8, 15, 16, 10, 13 and 14 operating to rooms, 14, 8, 18, 15, 7 and 17 are connected to Meter F-G. This is a 3-wire type meter.

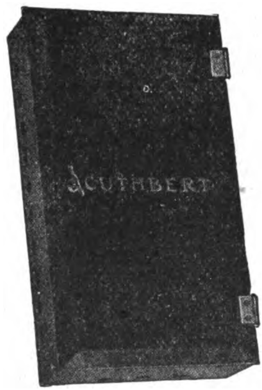


Figure 198.

This panelboard occupies a very small amount of space and all wire connections are made permanently on the face of the panelboard. This prevents improper meter connections and enables the tenant to readily trace the circuits connected to his meter.

This type of panelboard can be used to advantage for metering current owing to the fact that repeated changes in connection of the circuit wires to meters can be made without the use of loose wiring connections and the consequent fire hazard.

70. Cabinets.

(See Figure 198.)

For panel and distributing boards, cut-outs and switches.

(For installation rule see Nos. 8 d, 19 b-d, 23 c and 24 b.)

a. Design.

Must in all cases be so constructed as to insure ample strength and rigidity and be dust tight.

The hard usage to which cabinets are often subjected, especially during process of installation, makes it necessary so to construct them that they will be strong enough to keep their shape, thus permitting doors to close tightly and making possible the proper installation of wiring and conduit.

When doors are of metal, and less than 0.109 inch (No. 12 U. S. gage) in thickness and are not lined with insulating material there must be a space of at least one inch between the door and an enclosed fuse or any live metal part. A space of at least two inches must be provided between open-link fuses and metal, metal-lined or glass paneled doors of cabinets. Except as above specified there must be a space of at least one-half inch between the walls, back or door of any cabinet and any exposed live metal part. Cabinets must be deep enough to allow the door to be closed when switches rated at 30 amperes or less are in any position, and when larger switches are thrown open as far as their construction or installation will permit.

There must be a space of at least one-half inch between the walls and back of any cabinet and the nearest exposed current-carrying part.

b. Material.

May be either of cast or sheet metal, wood or approved composition. Wooden or composition cabinets must not be used on metal conduit, armored cable or metal moulding systems.

All metal used in construction of cabinets including linings, if any, must be thoroughly painted or otherwise treated to prevent corrosion.

c. **Wooden Cabinets.**

Wood must be well seasoned and at least three-fourths inch thick and be thoroughly filled and painted, and must be lined with a non-combustible material.

d. **Linings.**

In all cabinets, linings of slate, marble or approved composition must be at least one-fourth inch thick and firmly secured in place; when metal is used for the lining it must be at least No. 16 U. S. gage in thickness. For lining wooden

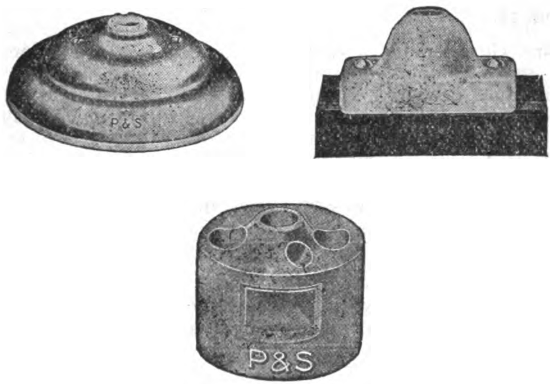


Figure 199.

cabinets one-eighth inch rigid asbestos board may be used when firmly secured in place by screws or tacks.

e. **Composition Cabinets.**

Only approved material should be used. and in no case less than three-fourths of an inch in thickness.

f. **Metal Cabinets.**

If cast metal is used a thickness of at least one-eighth inch must be provided. Sheet metal must not be less than

.0625 inch thick (No. 16 U. S. gage), and must in every case be of sufficient thickness or so reinforced as to comply with Section *(a)* *"Design."* In steel cabinets having an area of more than 360 square inches for any surface, or having a single dimension greater than 2 feet, sheet metal must be used at least No. 14 U. S. gage in thickness; in those having an area of more than 1,200 square inches for any surface, or having a single dimension greater than 4½ feet, the sheet metal must be at least No. 12 U. S. gage in thickness.

g. **Doors.**

Must close against a rabbet or have flanges over edges so as to make cabinets dust tight. Hinges must be of strong and durable design. A substantial latch or catch must be provided so as to keep the door closed, and a lock may be used in addition to the catch if desired.

When doors have glass panels the glass must be at least one-eighth inch thick (commercial thickness), and must not have a greater area than 450 square inches unless plate glass at least one-fourth inch in thickness is used.

h. **Marking.**

Must be marked with manufacturer's name where the name can be plainly seen when the cabinet is installed.

71. Rosettes.

(See Figure 199.)

Ceiling rosettes, both fused and fuseless, must be constructed in accordance with the following specifications:—

a. **Base.**

Current-carrying parts must be mounted on non-combustible, non-absorptive, insulating bases. There should be no openings through the rosette base except those for the supporting screws and in the concealed type for the conductors also, and these openings should not be made any larger than necessary.

There must be at least one-fourth inch space, measured over the surface, between supporting screws and current-carrying parts. The supporting screws must be so located or countersunk that the flexible cord cannot come in contact with them.

Bases for the knob and cleat type must have at least two holes for supporting screws; must be high enough to keep the wires and terminals at least one-half inch from the surface to which the rosette is attached, and must have a porcelain lug under each terminal to prevent the rosette from being placed over projections which would reduce the separation to less than one-half inch.

Bases for the moulding and conduit box types must be high enough to keep the wires and terminals at least three-eighths inch from the surface wired over.

b. **Mounting.**

Contact pieces and terminals must be secured in position by at least two screws, or made with a square shoulder, or otherwise arranged to prevent turning.

The nuts or screw heads on the under side of the base must be countersunk not less than one-eighth inch and covered with a waterproof compound which will not melt below 150 degrees Fahrenheit (65 degrees Centigrade).

c. **Terminals.**

Line terminal plates must be at least .06 inch in thickness, and terminal screws must not be smaller than No. 6 standard screw with about 32 threads per inch.

Terminal plates for the flexible cord and for fuses must be at least .06 inch in thickness. The connection to these plates shall be by binding screws not smaller than No. 5 standard screw with about 40 threads per inch. At all binding screws for line wires and for flexible cord, up-turned lugs, or some equivalent arrangement, must be provided which will secure the wires being held under the screw heads.

d. **Cord Inlet.**

The diameter of the cord inlet hole should measure thirteen thirty-seconds inch in order that standard portable cord may be used.

e. **Knot Space.**

Ample space must be provided for a substantial knot tied in the cord as a whole.

All parts of the rosette upon which the knot is likely to bear must be smooth and well rounded.

f. **Cover.**

When the rosette is made in two parts, the cover must be secured to the base so that it will not work loose.

In fused rosettes, the cover must fit closely over the base so as to prevent the accumulation of dust or dirt on the inside, and also to prevent any flash or melted metal from being thrown out when the fuses melt.

g. **Marking.**

Must be plainly marked where it may readily be seen after the rosette has been installed, with the name or trade-mark of the manufacturer, and the rating in amperes and volts. Fuseless rosettes may be rated 3 amperes, 250 volts; fused rosettes, with link fuses, not over 2 amperes, 125 volts.

h. **Test.**

Fused rosettes must have a fuse in each pole and must operate successfully when short-circuited on the voltage for which they are designed, the test being made with the two fuses in circuit.

When link fuses are used the test shall be made with fuse wire which melts at about 7 amperes in one-inch lengths. The larger fuse is specified for the test in order to more nearly approximate the severe conditions obtained when only one 2-ampere fuse (the rating of the rosette) is blown at a time.

Fused rosettes equipped with enclosed fuses are much preferable to the link fuse rosettes.

72. Sockets.

(See Figure 200.)

(For installation rules, see No. 31.)

Sockets of all kinds, including wall receptacles, must be constructed in accordance with the following specifications:—

a. **Marking.**

All sockets and receptacles must be marked with the manufacturer's name or trade-mark. All sockets and receptacles must be marked as given in the following sections.

b. Ratings.

Key Sockets.—The Standard key socket (any socket having Standard Edison screw shell and ordinary "slow make" switch) to be rated 250 watts, 250 volts.

Marking may be 250 W., 250 V. This rating shall not be interpreted to permit the use, at any voltage, of current above 2½ amperes on any standard key or pull socket.

A key socket with Standard Edison shell and special switch which "makes" and "breaks" with a quick snap and does not stop when motion has been once imported by the button or handle, may be rated 660 watts, 250 volts (660 W., 250 V.).

Miniature and Candelabra key sockets to be rated 75 watts, 125 volts (75 W., 125 V.).

Keyless Sockets.—Standard keyless sockets with Standard Edison screw shell to be rated 660 watts, 250 volts (660 W., 250 V.). This rating shall not be interpreted to permit the use, at any voltage, of current above 6 amperes on any keyless socket.

Weatherproof sockets with Standard Edison shell and having no exposed current carrying parts may be rated 660 watts, 600 volts (660 W., 600 V.).

Miniature and Candelabra keyless sockets to be rated 75 watts, 125 volts (75 W., 125 V.).

Double Ended Sockets.—Each Edison screw shell to be rated at 250 watts, 250 volts for key type, 660 watts, 250 volts for keyless type, the devices being marked with a single marking applying to each lamp holder.

These ratings shall not be interpreted to permit the use at any voltage, of current above 2½ amperes for key type, or above 6 amperes for keyless types.

c. Shell.

Metal used for shells must be moderately hard, but not hard enough to be brittle or so soft as to be easily dented or knocked out of shape. Brass shells must be at least thirteen one-thousandths of an inch in thickness, and shells of any other material must be thick enough to give the same stiffness and strength as the required thickness of brass.

d. Lining.

The inside of the shells must be lined with insulating material, which must absolutely prevent the shell from becoming a part of the circuit, even though the wires inside the sockets should become loosened or detached from their position under the terminal screws.

The material used for lining must be at least one thirty-second of an inch in thickness, and must be tough and tenacious. It must not be injuriously affected by the heat from the largest lamp permitted in the socket, and must leave water in which it is boiled practically neutral. It must be so firmly secured to the shell that it will not fall out with ordinary handling of the socket. It is preferable to have the lining in one piece.

The cap must also be lined, and this lining must comply with the requirements for shell linings.

The shell lining should extend beyond the shell far enough so that no part of the lamp base is exposed when a lamp is in the socket.

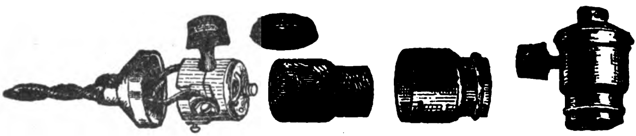


Figure 200.

The standard Edison lamp base measures fifteen-sixteenths inches in a vertical plane from the bottom of the center contact to the upper edge of the screw shell.

In sockets and receptacles of standard forms a ring of any material inserted between an outer metal shell of the device and the inner screw shell for insulating purposes and separable from the device as a whole, is considered an undesirable form of construction. This does not apply to the use of rings in lamp clusters or in devices where the outer shell is of porcelain, where such rings serve to hold the several porcelain parts together, and are thus a necessary part of the whole structure of the device.

e. Cap.

Caps, when of sheet brass, must be at least thirteen one-thousandths of an inch in thickness, and when cast or made of other metals must be of equivalent strength. The inlet piece, except for special sockets, must be tapped with a standard one-eighth inch pipe thread. It must contain sufficient metal for a full, strong thread, and when not in one piece with the cap, must be joined to it in such a way as to give the strength of a single piece.

There must be sufficient room in the cap to enable the ordinary wireman to easily and quickly make a knot in the cord and to push it into place in the cap without crowding. All parts of the cap upon which the knot is likely to bear must be smooth and well insulated.

The cap lining called for in the note to Section *d* will provide a sufficiently smooth and well-insulated surface for the knot to bear upon.

Sockets with an outlet threaded for three-eighths-inch pipe will, of course, be approved where circumstances demand their use. This size outlet is necessary with most stiff pendants and for the proper use of reinforced flexible cord, as explained in the note to No. 32 *d*.

f. Frame and Screws.

The frame which holds the moving parts must be sufficiently heavy to give ample strength and stiffness.

Brass pieces containing terminal screws must be sufficiently heavy to give ample strength and stiffness, and have at least six one-hundreths of an inch of thread for terminal screws.

Terminal post screws must not be smaller than No. 5 standard screw, with about forty threads per inch.

g. Spacing.

Points of opposite polarity must everywhere be kept not less than three sixty-fourths of an inch apart, unless separated by a reliable insulation.

h. Connections.

The connecting points for the flexible cord must be made to very securely grip a No. 16 or 18 B. & S. gage conductor. An up-turned lug, arranged so that the cord may be gripped between the screw and the lug in such a way that it cannot possibly come out, is strongly advised.

i. Lamp Holder.

The socket must firmly hold the lamp in place so that it cannot be easily jarred out and must provide a contact good enough to prevent undue heating with the maximum current allowed. The holding pieces, springs and the like, if a part of the circuit, must not be sufficiently exposed to allow them to be brought in contact with anything outside of the lamp and socket.

j. **Base.**

The base on which current carrying parts are mounted must be of porcelain and all insulating material used must be of approved material.

k. **Key.**

The socket key-handle must be of such a material that it will not soften from the heat of a fifty candle-power lamp hanging downwards from the socket in air at 70 degrees Fahrenheit (21 degrees Centigrade), and must be securely, but not necessarily rigidly, attached to the metal spindle which it is designed to turn.

l. **Sealing.**

All screws in porcelain pieces, which can be firmly sealed in place, must be so sealed by a waterproof compound which will not melt below 200 degrees Fahrenheit (93 degrees Centigrade).

m. **Putting Together.**

The socket as a whole must be so put together that it will not rattle to pieces. Bayonet joints or an equivalent are recommended.

n. **Test.**

The socket when slowly turned "on and off" at a rate not to exceed ten times per minute, while carrying a load of one ampere at 250 volts, must "make" and "break" the circuit 6,000 times before failing and must operate successfully at 50 per cent overload in amperes at both 125 and 250 volts direct current under the most severe conditions which they are liable to meet in practice.

o. **Keyless Sockets.**

Keyless sockets of all kinds must comply with the requirements for key sockets as far as they apply.

p. Sockets of Insulating Material.

Sockets made of porcelain or other insulating material must conform to the above requirements as far as they apply, and all parts must be strong enough to withstand a moderate amount of hard usage without breaking.

Porcelain shell sockets being subject to breakage, and constituting a hazard when broken, will not be accepted for use in places where they would be exposed to hard usage.

q. Inlet Bushing.

When the socket is not attached to a fixture, the threaded inlet must be provided with a strong insulating bushing having a *smooth* hole at least nine thirty-seconds of an inch in diameter. The edges of the bushing must be rounded

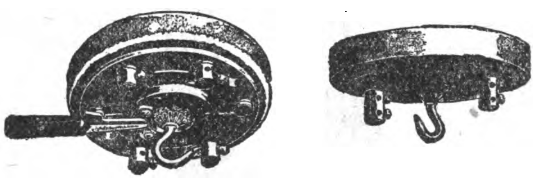


Figure 201.

and all inside fins removed, so that in no place will the cord be subjected to the cutting or wearing action of a sharp edge.

Bushings for sockets having an outlet threaded for three-eighths-inch pipe should have a hole thirteen thirty-seconds of an inch in diameter, so that they will accommodate *approved* reinforced flexible cord.

73. Hanger-Boards for Series Arc Lamps.

(See Figure 201.)

(For installation rules see Nos. 21 d and 22 b.)

a. Hanger-boards must be so constructed that all wires and current-carrying devices thereon will be exposed to view and thoroughly insulated by being mounted on a non-combustible, non-absorptive, insulating substance. All switches attached to the same must be so constructed that they shall be automatic in their action, cutting off both poles to the lamp, not stopping between points when started and preventing an arc between points under all circumstances.

74. Arc Lamps.

(See Figure 202.)

(For installation rules see Nos. 21 and 33.)

a. Must be provided with reliable stops to prevent carbons from falling out in case the clamps become loose.

b. All exposed parts must be carefully insulated from the circuit.

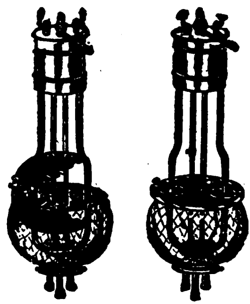


Figure 202.

c. Must, for constant-current systems, be provided with an *approved* hand switch, and an automatic switch that will shunt the current around the carbons, should they fail to feed properly.

The hand switch to be approved, if placed anywhere except on the lamp itself, must comply with requirements for switches on hanger-boards as laid down in No. 73.

d. Terminals must be designed to secure a thoroughly good and permanent contact with the supply wires, which contact must not become loosened by motion of the lamp during trimming.

75. Spark Arresters.

(See Figure 202.)

(For installation rules see Nos. 21 c and 33 c.)

a. Spark arresters must so close the upper orifice of the globe that it will be impossible for any sparks, thrown off by the carbons, to escape.

76. Insulating Joints.

(For installation rules, see No. 30 a.)

a. Must be entirely made of material that will resist the action of illuminating gases and will not give way or soften under the heat of an ordinary gas flame or leak under a moderate pressure. Must be so arranged that a deposit of moisture will not destroy the insulating effect; must show a dielectric strength between gas-pipe attachments sufficient to resist throughout five minutes the application of an electro-motive force of 4,000 volts; and must be sufficiently strong to resist the strain to which they are liable to be subjected during installation.

Insulating joints having soft rubber in their construction will not be approved.

77. Fixtures.

(For installation rules, see Nos, 24 e, and 26 v to y. For construction of Wires, see No. 55.)

a. Material.

Must be of metal or hard wood, except that other approved material may be used if re-enforced by metal or otherwise constructed to secure requisite mechanical strength.

In all cases mechanical strength must be secured practically equivalent to an all-metal fixture of similar size and form.

b. Assembly.

All arms must be reliably secured to prevent turning. Arms of threaded tubing must not be lighter than No. 18 B. & S. gage, and with screw joints of arms there must be not less than five threads all engaging. All methods of fastening arms or making joints between metal parts by soldering, brazing or otherwise, must be such as to secure in every case ample strength and reliability.

c. **Sockets.**

Must, except on pendant cords, be attached to the metal of the fixtures and must be secured in a reliable and permanent manner.

Receptacles having exposed terminals must not be used in canopies or in any part of fixtures unless completely enclosed in metal.

d. **Wireways.**

All burrs, fins and sharp edges liable to injure wire coverings must, where practicable, be removed or rounded, but in every case it must be possible to pull in and also to withdraw the wires without injuring them. Where supply wires enter fixture stems or casings there must be suitable fittings having smooth rounded edges to prevent injury to the wire coverings.

In non-metallic fixtures wireways must be metal-lined unless approved armored conductors with suitable fittings are used.

On chains or similar parts where conductors are not completely enclosed in metal, wires must be stranded and must have rubber insulation not less than one thirty-second inch in thickness or approved pendant or portable cord may be used.

e. **Markings.**

Must be marked with the manufacturer's name or trademark.

f. **Test.**

Must be tested in an approved manner for short circuits between conductors and for contacts between conductors and metal parts of fixtures.

78. Rheostats, Resistance Boxes and Equalizers.

(For installation rules, see Nos. 4 a and 8 c.)

a. **Materials.**

Must be made entirely of non-combustible materials, except such minor parts as handles, magnet insulation, etc. All segments, lever arms, etc., must be mounted on non-combustible non-absorptive, insulating material.

Rheostats used in dusty or linty places or where exposed to flyings of combustible material, must be so constructed that even if the resistive conductor be fused by excessive current, the arc or any attendant flame will be quickly and safely extinguished. Rheostats used in places where the above conditions do not exist may be of any approved type.

Wood or other suitable material may be used for parts of the casings or covers of drum controllers, providing these parts are properly lined or treated with fire-resisting materials, and so arranged that should the combustible parts within the casing be ignited, the fire would be confined within the casing or cover.

In drum controllers and apparatus of like nature where the controlling mechanism is entirely enclosed in a substantial tight metal case or compartment, hard wood or other suitable material may be used for bases for mounting current-carrying parts, or for other parts which cannot readily be made of non-combustible material, provided such combustible material is present only in such amount and so disposed that, even if it be totally destroyed by fire or excessive heat, the effect shall be confined to the interior of the case.

b. **Construction.**

Must be so constructed that when mounted on a plane surface the casing will make contact with such surface only at the points of support. An air space of at least one-fourth inch between the rheostat casing and the supporting surface will be required.

The construction throughout must be heavy, rugged and thoroughly workmanlike.

c. **Connections.**

Clamps for connecting wires to the terminals must be of a design which will insure a thoroughly good connection, and must be sufficiently strong and heavy to withstand considerable hard usage. For currents above fifty amperes, lugs firmly screwed or bolted to the terminals, and into which the connecting wires shall be soldered, must be used.

Clamps or lugs will not be required when leads designed for soldered connections are provided.

d. **Marking.**

Must be plainly marked, where it may be readily seen after the device is installed, with the rating and the name of the maker; and the terminals of motor-starting rheostats must be marked to indicate to what part of the circuit each is to be connected, as "line," "armature" and "field."

e. **Contacts.**

The design of the fixed and movable contacts and the resistance in each section must be such as to secure the least tendency toward arcing and roughening of the contacts, even with careless handling or the presence of dirt.

In motor-starting rheostats, the contact at which the circuit is broken by the lever arm when moving from the running to the starting position, must be so designed that there will be no detrimental arcing. The final contact, if any, on which the arm is brought to rest in the starting position must have no electrical connection.

Experience has shown that sharp edges and segments of thin material help to maintain an arc, and it is recommended that these be avoided. Segments of heavy construction have a considerable cooling effect on the arc, and rounded corners tend to spread it out and thus dissipate it.

It is recommended that the circuit-breaking contacts be so constructed as to "break" with a quick snap, independently of the slowness of movement of the operator's hand, or that a magnetic blowout or equivalent device be used. For dial type rheostats the movable contact should be flexible in a plane at right angles to the plane of its movement, and for medium and larger sizes the stationary contacts should be readily renewable.

f. **No-Voltage Release.**

Motor-starting rheostats must be so designed that the contact arm cannot be left on intermediate segments, and for direct current circuits must be provided with an automatic device which will interrupt the supply circuit before the speed of the motor falls to less than one-third of its normal value. In motor starting rheostats for alternating current circuits the automatic interrupting device may be omitted.

g. **Overload Release.**

Overload release devices which are inoperative during the process of starting a motor will not be approved, unless other circuit-breakers or fuses are installed in connection with them.

If, for instance, the over-load release device simply releases the starting arm and allows it to fly back and break the circuit, it is inoperative while the arm is being moved from the starting to the running position.

h. **Test.**

Must, after 100 operations under the most severe normal conditions for which the device is designed, show no serious burning of the contacts or other faults, and the release mechanism of motor-starting rheostats must not be impaired by such a test.

Field rheostats, or main-line regulators intended for continuous use, must not be burned out or depreciated by carrying the full normal current on any step for an indefinite period. Resistances intended for intermittent use (such as on electric cranes, elevators, etc.) must be able to carry their rated current on any step for as long a time as the character of the apparatus which they control will permit them to be used continuously.

Starting duty resistances shall either be so constructed that if the resistance conductor be fused the arc, or any attendant flame or molten droppings, shall be confined within the rheostat; or they shall be constructed with such capacity that when the rated full-load current is passed through the entire resistance for a period of five minutes there shall be no resultant flaming, or molten droppings.

Continuous duty resistances shall either be so constructed that if the resistive conductor be fused the arc or any attendant flame or molten droppings shall be confined within the rheostat or they shall be constructed with such capacity that if subjected to a current flow throughout the entire rheostat, 25 per cent in excess of that at which they are rated, for a period of two hours, there shall be no resultant flaming or molten droppings.

79. Auto-Starters.

(For installation rules see No. 8 d.)

Construction and Test of Auto-starters Ranging to a Maximum of 100 Horse Power and 3,500 Volts.

Under this class are included all such devices for starting A. C. Motors as employ transformer windings whereby the potential impressed upon the motor terminals during process of starting may be made less than the full line voltage and which have switching devices for accomplishing this result.

Apparatus designed for starting A. C. Motors by employing ohmic resistance coils are to be judged under No. 78—Rheostats.

a. Construction.

Coils and switches of auto-starters used in dusty and linty places or where exposed to flyings of combustible material, must be completely enclosed in substantial metal cases so constructed as to effectually exclude ordinary dust, lint or flyings of combustible material.

Auto-starters used in places where the above conditions do not exist, may be of any approved type.

Cases for either transformer coils or switches must provide for access to the interior for inspection and for renewal of oil, and must be so constructed that when mounted on a plain surface the casing will make contact with such surface only at points of support. An air space at least one-fourth of an inch between the casing and supporting surface will be required.

The oil tank shall be marked in a suitable manner to indicate the proper oil level.

The switch must provide an off position, or running position and at least one starting position. It must be so arranged that it will be held in off and running positions but cannot be left in a starting position or without the proper running overload protective devices in the circuit.

The construction throughout must be thoroughly substantial.

b. Connections.

Clamps for connecting wires to the terminal board must be of a design which will insure a thoroughly good connection and must be sufficiently strong and heavy to withstand considerable hard usage. For currents above 50 amperes, lugs firmly screwed or bolted to the terminal boards, and into which the connecting wires shall be soldered, must be used. Clamps or lugs will not be required when leads designed for soldered connections are provided.

c. Marking.

Must be plainly marked, where it may be readily seen after the device is installed, with the rating and name of the maker; terminals to be so marked as to indicate to what part of the circuit each is to be connected.

d. **Insulation Test.**

The insulation of the completely assembled apparatus must withstand for one minute a potential test between live metal parts and frame core and case as follows:—

Rated Terminal Voltage of Circuit.	Testing Voltage.
Not exceeding 400 volts	1,500 volts
401-800	2,000 volts
801-1,200	3,500 volts
1,201-2,500	5,000 volts
2,500 up	Double normal rated Voltages

e. **Tests.**

With full line voltage applied to line terminals and current taken from taps giving between 40 and 60 per cent of the normal line voltage, 300 per cent of full load current of the motor applied for the first fifteen seconds of each four-minute period for one hour must show no resultant flaming or molten droppings. The oil, if any, in which the transformer windings are immersed shall not overflow the containing case and the entire starter shall be practically uninjured.

80. Reactive Coils and Condensers.

a. Reactive coils must be made of non-combustible material, mounted on non-combustible bases and treated, in general, as sources of heat.

b. Condensers must be treated like other apparatus operating with equivalent voltage and currents. They must have non-combustible cases and supports, and must be isolated from all combustible materials and, in general, treated as sources of heat.

81. Transformers.

(For installation rules see Nos. 11, 14, 15, 36 and 45.)

a. Must not be placed in any but metallic or other non-combustible cases.

It is advised that every transformer with either primary or secondary voltages over 550 volts to be so designed and connected that the middle point of the secondary coil can be reached, if, at any future time, it should be desired to ground it.

b. Must be plainly marked where it may be readily seen after the transformer is installed, with the name of the maker, with the primary and secondary voltages and the rated capacity.

c. Must be constructed to comply with the following tests:—

1. Shall be run for a sufficient time to reach a practically constant temperature at full rated load, and at the end of that time a rise in temperature, as measured by the increase in resistance of the windings, shall not exceed 50 degrees Centigrade (122 degrees Fahrenheit).
2. When heated to normal full load operating temperature, the insulation of transformers shall withstand continuously for one minute a difference of potential (alternating) between primary and secondary coils and between the primary coils and the core according to the following table:—

Primary or Secondary Voltage.	Test Voltage.
Not exceding 400 volts	1,500
From 400 to 550 volts	2,000
Over 550 volts	To follow the standardization rules of the American Institute of Electrical Engineers.

82. Lightning Arresters.

(For installation rules, see No. 5.)

a. Lightning arresters must be of *approved* construction. (See list of Electrical Fittings.)

83. Electric Signs (for Low-Potential Systems only).

(For installation rules, see No. 23 d.)

a. Material.

Must be constructed entirely of metal or other approved non-combustible material except that wood may be used on outside for decoration if kept at least two inches from nearest lamp receptacles.

Sheet metal must be not less than No. 28 U. S. metal gage.

All metal must be galvanized, enameled or treated with at least three coats of anti-corrosive paint, or otherwise protected in an approved manner against corrosion.

b. **Construction.**

Must be so constructed as to secure ample strength and rigidity.

Must be so constructed as to be practically weatherproof and so as to enclose all terminals and wiring other than the supply leads, except that open work will be permitted for signs on roofs or open ground where not subject to mechanical injury, provided the wiring is in accordance with Section "e" below.

Cut-outs, transformers, unless of weatherproof type, flashers and other similar devices on or within the sign structure, must be in a separate, completely enclosed, accessible and weatherproof compartment, or, in a substantial weatherproof box or cabinet of metal of thickness not less than that of the metal of the sign itself.

Each compartment must have suitable provision for drainage through one or more holes each not less than one-quarter inch in diameter.

c. **Marking.**

Must have the maker's name or trademark permanently attached to the exterior.

d. **Receptacles.**

Must be so designed as to afford permanent and reliable means to prevent possible turning; must be so designed and placed that terminals will be at least one-half inch from other terminals and from metal of the sign except that where open work is permitted, this separation must be one inch.

Miniature receptacles will not be approved for use in outdoor signs.

e. **Wiring.**

Must be approved rubber covered, not less than No. 14 B. and S. gage, and, except where open work is permitted, must be double braided.

Must be neatly run, and so disposed and fastened as to be mechanically secure.

Must be soldered to terminals, and exposed parts of wires and terminals must be treated to prevent corrosion.

Must, where they pass through walls or partitions of the sign, be protected by approved bushings.

On outside of sign structure, except where open work is permitted, must be in approved metal conduit or in approved armored cable.

For open work, wire must be rigidly supported on non-combustible, non-absorptive insulators, which separate the wires at least one inch from the surface wired over. Rigid supporting requires, under ordinary conditions where wiring over flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distances between supports should be shortened. In those parts of circuits where wires are connected to approved receptacles which hold them at least one inch from surface wired over, and which are placed not over one foot apart, such receptacles will be considered to afford the necessary support and spacing of the wires. Between receptacles more than one foot, but less than two feet apart, an additional non-combustible, non-absorptive insulator maintaining a separation and spacing equivalent to the receptacles must be used. Except as above specified, wires must be kept apart at least two and one-half inches for voltages up to 300, and four inches for higher voltages.

f. Leads from sign must pass through the walls of sign either through approved metal conduit or armored cable, or must be neatly cabled and pass through one or more approved non-combustible, non-absorptive bushings.

g. Not over 1,320 watts shall be dependent upon final cut-out.

SIGN HANGING.

The N. E. Code recognizes none but signs made entirely of metal, nevertheless there are at the present time many signs of wood construction installed and in Figure 203 such a sign is shown. In the hanging of these old wooden signs certain

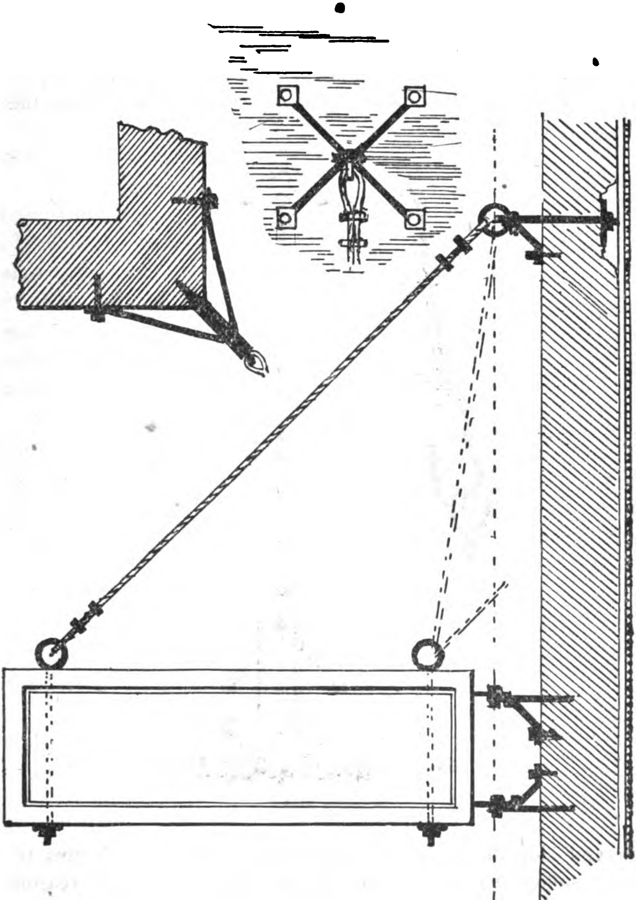


Figure 203.

precautions are necessary that are not called for in connection with metallic signs. The framework of a wood sign is generally made up as indicated in Figure 204 and where the

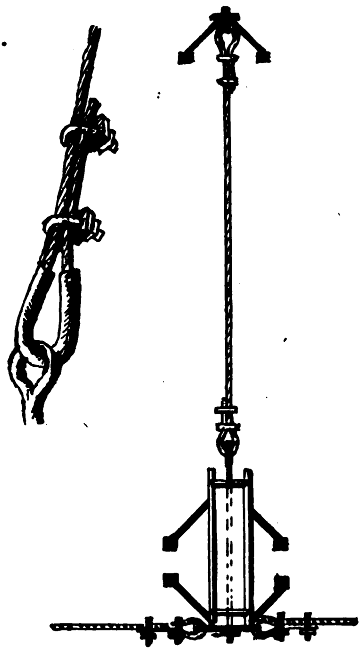


Figure 204.

top and side pieces come together the wood soon begins to decay sufficiently to weaken the structure. For this reason the cross pieces on the supporting bolts should be long enough to catch the outside boards of sign as these carry the letters and make up nearly the whole weight of the sign. The manner of supporting the rear end of sign is also open to serious objections and if the sign is at all heavy it is advisable to provide an extra bolt at rear and attach this to an extra cable as shown by broken lines, Figure 203.

If signs are required to swing as they are in many cities it will be necessary to arrange the turning points at top end of cable to be perpendicularly above the turning points at sign otherwise the sign will not swing level.

Wherever possible signs should be supported by bolts passing through brick or stone walls. The fronts of such walls are not always of the best and usually consist of veneering which is merely stuck on and quite flimsy.

In Figure 205 is shown the cross-section of an expansion bolt which has shown itself to be very serviceable. It is made of the shape shown, the black portion representing a lead sleeve which surrounds the bolt. After the bolt is in place the lead is pounded in with a small piece of pipe. The lead thus forced in expands into every crevice in the drill hole thus, not only holding the bolt very tight, but also excluding all water that might cause corrosion or decay. If the brick or stone itself is secure this form of support is very substantial.

The supports to a sign should always be arranged as high above the sign as possible if dependence is to be placed upon expansion bolts. At low angles the pull is almost straight out from the wall while at a high elevation the pull is downward.

The side strain on side guys in a storm is much greater than the weight of the sign imposes upon them in support but of course a side guy giving way, if the sign is arranged to swing, does not necessarily allow the sign to fall. The wind pressure in heavy storms and at velocities often met with in narrow streets is 30 pounds or more per square foot. This for a sign 10 by 3 feet equals 900 pounds, while a sign of this size would not ordinarily weigh above 300.

The side guys should be spread at least at an angle of 45 degrees and where this is not possible stiff braces should preferably be used on both sides. If such guys are tight there will not only be a pull against the wind but a push also.

Wherever the cables are attached to sign they should be protected by sleeves and clamped together by two clips as

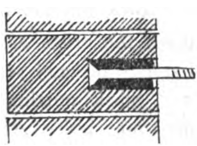


Figure 205.

shown in the figure. Good galvanized cable should be used. A poor cable in the center of a large city will show strong evidence of rusting in less than a year, while a good one will last a very long time. In the outskirts the effect of rust is less marked and most any galvanized cable will last several years.

It is good practice to remove any cable that shows the slightest evidence of rusting. In the early days of electric sign hanging quite frequently old elevator cables were used for that purpose. Several of these rusted fast enough to part in less than a year.

84.

Left blank for future use.

CLASS E.

MISCELLANEOUS.

85. Signaling Systems.

Governing wiring for telephone, telegraph (except wireless telegraph apparatus), district messenger and call-bell circuits, fire and burglar alarms, and all similar systems which are hazardous only because of their liability to become crossed with electric light, heat or power circuits.

a. Outside wires should be run in underground ducts or strung on poles, and kept off of the roofs of buildings, except by special permission of the Inspection Department having jurisdiction, and must not be placed on the same cross-arm with electric light or power wires. They should not occupy the same duct, manhole or handhole of conduit systems with electric light or power wires.

Single manholes, or handholes separated into sections by means of partitions of brick or tile will be considered as conforming with the above rule.

The liability of accidental crossing of overhead signaling circuits with electric light and power circuits, may be guarded against to a considerable extent by endeavoring to keep the two classes of circuits on different sides of the same street.

When the entire circuit from Central Station to building is run in underground conduits, Sections b to m inclusive do not apply.

b. When outside wires are run on same pole with electric light or power wires, the distance between the two inside pins of each cross-arm must not be less than twenty-four inches.

Signaling wires being smaller and more liable to break and fall, should generally be placed on the lower cross-arms.

When the wires are carried in approved cables, the next three sections (c, d and e) do not apply.

c. Where wires are attached to the outside walls of buildings, they must have an *approved* rubber insulating covering.

and on frame buildings or frame portions of other buildings shall be supported on glass or porcelain insulators, or knobs.

d. The wires from last outside support to the cut-outs or protectors must be of copper, and must have an *approved* rubber insulation. Must be provided with drip loops immediately outside the building and at entrance.

e. Wires must enter building through approved non-combustible, non-absorptive, insulating bushings sloping upward from the outside.

Installations where the Current-carrying Parts of the Apparatus Installed are Capable of Carrying Indefinitely a Current of Ten Amperes.

f. An all-metallic circuit shall be provided, except in telegraph systems.

g. At the entrance of wires to building, *approved* single pole cut-outs, designed for 251-600 volts potential and containing fuses rated at not over ten amperes capacity, shall be provided for each wire. These cut-outs must not be placed in the immediate vicinity of easily ignitible stuff, or where exposed to inflammable gases, or dust or to flying of combustible material.

h. The wires inside building shall be of copper not less than No. 16, B. & S. gage, and must have insulation and be supported, the same as would be required for an installation of electric light or power wiring, 0-600 volts potential.

i. The instruments shall be mounted on bases constructed of non-combustible, non-absorptive, insulating material. Holes for the supporting screws must be so located or countersunk, that there will be at least one-half inch space, measured over the surface, between the head of the screw and the nearest live metal part.

Installations where the Current-carrying Parts of the Apparatus Installed are Not Capable of Carrying Indefinitely a Current of Ten Amperes.

j. Must be provided with an *approved* protective device located as near as possible to the entrance of wires to building. The protector must not be placed in the immediate vicinity of easily ignitible stuff, or where exposed to inflammable gases or dust or flyings of combustible materials.

k. Wires from entrance to building to protector must be supported on porcelain insulators, so that they will come in contact with nothing except their designed supports.

l. The ground wire of the protective device shall be run in accordance with the following requirements:—

1. Shall be of copper and not smaller than No. 18 B. & S, gage.
2. Must have an insulating covering *approved* for voltages from 0 to 600, except that the preservative compound may be omitted.
3. Must run in as straight a line as possible to a good permanent ground. This may be obtained by connecting to a water or gas pipe connected to the street mains or to a ground rod or pipe driven in permanently damp earth. When connections are made to pipes, preference shall be given to water pipes. If attachment is made to gas pipe, the connection in all cases must be made between the meter and the street mains. In every case the connection shall be made as near as possible to the earth.

When the ground wire is attached to a water pipe or a gas pipe, it may be connected by means of an approved ground clamp fastened to a thoroughly clean portion of said pipe, or the pipe shall be thoroughly cleaned and tinned with rosin flux solder, and the ground wire shall then be wrapped tightly around the pipe and thoroughly soldered to it.

When the ground wire is attached to a ground rod driven into the earth, the ground wire shall be soldered to the rod in a similar manner.

Steam or hot-water pipes must not be used for a protector ground.

m. The protector to be approved must comply with the following requirements:—

For Instrument Circuits of Telegraph Systems.

1. An *approved* single pole cut-out, in each wire, designed for 2,000 volts potential, and containing

fuses rated at not over one ampere capacity. When main line cut-outs are installed as called for in section *g*, the instrument cut-outs may be placed between the switchboard and the instrument as near the switchboard as possible.

For all Other Systems.

1. Must be mounted on non-combustible, non-absorptive, insulating bases, so designed that when the protector is in place, all parts which may be alive will be thoroughly insulated from the wall to which the protector is attached.
2. Must have the following parts:—

A lightning arrester which will operate with a difference of potential between wires of not over 500 volts, and so arranged that the chance of accidental grounding is reduced to a minimum.

A fuse designed to open the circuit in case the wire become crossed with light or power circuits. The fuse must be able to open the circuit without arcing or serious flashing when crossed with any ordinary commercial light or power circuit.

A heat coil, if the sensitiveness of the instrument demands it, which will operate before a sneak current can damage the nstrument the protector is guarding.

Heat coils are necessary in all circuits normally closed through magnet windings, which cannot indefinitely carry a current of at least five amperes.

The heat coil is designed to warm up and melt out with a current large enough to endanger the instruments if continued for a long time, but so small that it would not blow the fuses ordinarily found necessary for such instruments. The smaller currents are often called "sneak" currents.

3. The fuses must be so placed as to protect the arrester and heat coils, and the protector terminals must be plainly marked "line," "instrument," "ground."

An easily read abbreviation of the above words will be allowed.

The Following Rules Apply to All Systems whether the Wires from the Central Office to the Building are Overhead or Underground.

n. Wires beyond the protector, or wires inside buildings where no protector is used, must be neatly arranged and securely fastened in place in some convenient, workmanlike manner.

They must not come nearer than two inches to any electric light or power wire in the building, unless separated therefrom by some continuous and firmly fixed non-conductor creating a permanent separation; this non-conductor to be in addition to the regular insulation on the wire.

The wires would ordinarily be insulated, but the kind of insulation is not specified, as the protector is relied upon to stop all dangerous currents. Porcelain tubing or *approved* flexible tubing may be used for encasing wires where required as above.

o. Wires where bunched together in a vertical run within any building must have a fire-resisting covering sufficient to prevent the wires from carrying fire from floor to floor unless they are run either in non-combustible tubing or in a fireproof shaft, which shaft must be provided with fire stops at each floor.

Signaling wires and electric light or power wires may be run in the same shaft, provided that one of these classes of wires is run in non-combustible tubing, or provided that when run otherwise these two classes of wires shall be separated from each other by at least two inches.

In no case shall signaling wires be run in the same tube with electric light or power wires.

p. Transformers or other devices for supplying current to signaling systems from light, heat or power circuits must be of a design expressly approved for this purpose. The primary wiring must be installed in accordance with the rules for "Class C," and the secondary wiring in accordance with "Class E."

86. Wireless Telegraph Apparatus.

NOTE.—These rules do not apply to Wireless Telegraph apparatus installed on shipboard.

In setting up Wireless Telegraph apparatus (so-called) all wiring within the building must conform to the Rules and

Requirements of the National Electrical Code for the class of work installed and the following additional specifications:—

a. Aerial conductors to be permanently and effectively grounded at all times when station is not in operation by a conductor not smaller than No. 4 B. & S. gage copper wire, run in a direct line as possible to water pipe at a point on the street side of all connections to said water pipe within the premises, or to some other equally satisfactory earth connection.

b. Aerial conductors when grounded as above specified must be effectually cut off from all apparatus within the building.

c. Or the aerial to be permanently connected at all times to earth in the manner specified above, through a short-gap lightning arrester; said arrester to have a gap of not over .015 inch between brass or copper plates not less than 2½ inches in length parallel to the gap and 1½ inches the other way with a thickness of not less than one-eighth inch mounted upon non-combustible, non-absorptive, insulating material of such dimensions as to give ample strength. Other approved arresters of equally low resistance and equally substantial construction may be used.

d. In cases where the aerial is grounded as specified in paragraph 1, the switch employed to join the aerial to the ground connection shall not be smaller than a standard 100 ampere knife switch.

e. Where supply is obtained direct from the street service the circuit must be installed in approved metal conduits or armored cable. In order to protect the supply system from high potential surges, there must be inserted in circuit either a transformer having a ratio which will have a potential on the secondary leads not to exceed 550 volts, or two condensers in series across the line, the connection between said condensers to be permanently and effectually grounded. These condensers should have capacity of not less than one-half m. f.

87. Electric Gas Lighting.

a. Electric gas lighting, unless it is the *frictional* system, must not be used on the same fixture with the electric light.

88. Insulation Resistance.

The wiring in any building must test free from grounds;

i. e., the complete installation must have an insulation between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.) not less than that given in the following table:—

Up to 5 amperes	4,000,000 ohms.
Up to 10 amperes	2,000,000 ohms.
Up to 25 amperes	800,000 ohms.
Up to 50 amperes	400,000 ohms.
Up to 100 amperes	200,000 ohms.
Up to 200 amperes	100,000 ohms.
Up to 400 amperes	50,000 ohms.
Up to 800 amperes	25,000 ohms.
Up to 1,600 amperes	12,500 ohms.

The test must be made with all cut-outs and safety devices in place. If the lamp sockets, receptacles, electroliers, etc., are also connected, only one-half of the resistances specified in the table will be required.

89. Soldering Fluid.

a. The following formula for soldering fluid is suggested:—

Saturated solution of zinc chloride	5 parts
Alcohol	4 parts
Glycerine	1 part

Class F.

MARINE WORK.

90. Generators.

a. Must be located in a dry place.
b. Must have their frames insulated from their bed-plates.
c. Must each be provided with a waterproof cover.
d. Must each be provided with a name-plate, giving the maker's name, the capacity in volts and amperes, and the normal speed in revolutions per minute.

91. Wires.

a. Must be supported in *approved* moulding or conduit, except at switchboards and for portables.

Special permission may be given for deviation from this rule in dynamo-rooms.

b. Must have no single wire larger than No. 12 B. & S. gage. Wires to be stranded when greater carrying capacity is required. No single solid wire smaller than No. 14 B. & S. gage, except in fixture wiring to be used.

Stranded wires must be soldered before being fastened under clamps or binding screws, and when they have conductivity greater than that of No. 8 B. & S. gage copper wire they must be soldered into lugs.

c. Splices or taps in conductors must be avoided as far as possible. Where it is necessary to make them they must be so spliced or joined as to be both mechanically and electrically secure without solder. They must then be soldered, to insure preservation, covered with an insulating compound equal to the insulation of the wire, and further protected by a waterproof tape. The joint must then be coated or painted with a waterproof compound.

All joints must be soldered unless made with some form of *approved* splicing device.

For Moulding Work.

d. Must have an *approved* insulating covering at least three thirty-seconds of an inch in thickness and be covered with a substantial waterproof braid.

The physical characteristics shall not be affected by any change in temperature up to 200 degrees Fahrenheit (93 degrees Centigrade). After two weeks' submersion in salt water at 70 degrees Fahrenheit (21 degrees Centigrade), it must show an insulation resistance of 100 megohms per mile after three minutes' electrification with 550 volts.

e. Must have, when passing through water-tight bulkheads and through all decks, a metallic stuffing tube lined with hard rubber. In case of deck tubes, they must be boxed near deck to prevent mechanical injury.

f. Must be bushed with hard rubber tubing, one-eighth of an inch in thickness, when passing through beams and non-water-tight bulkheads.

For Conduit Work.

g. Must have an *approved* insulating covering.

The insulation for conductors, for use in lined conduits, to be approved, must be at least three thirty-seconds of an inch in thickness and be covered with a substantial waterproof braid. The physical characteristics shall not be affected by any change in temperature up to 200 degrees Fahrenheit (93 degrees Centigrade).

After two weeks' submersion in salt water at 70 degrees Fahrenheit (21 degrees Centigrade), it must show an insulation resistance of 100 megohms per mile after three minutes' electrification with 550 volts.

For unlined metal conduits, conductors must conform to the specifications given for lined conduits, and in addition have a second outer fibrous covering at least one thirty-second of an inch in thickness and sufficiently tenacious to withstand the abrasion of being hauled through the metal conduit.

h. Must not be drawn in until the mechanical work on the conduit is completed and same is in place.

i. Where run through coal bunkers, boiler rooms, and where they are exposed to severe mechanical injury, must be encased in *approved* conduit.

j. Must, for alternating systems, have the two or more wires of a circuit drawn in the same conduit.

The same conduit must not contain more than four two-wire, or three three-wire circuits of the same system, except by special permission of the Inspection Department having jurisdiction, and must never contain circuits of different systems.

It is suggested that this be done for direct current systems also, so that they may be changed to alternating systems at any time, induction troubles preventing such a change if the wires are in separate conduits.

92. Portable Conductors.

a. Must be made of two stranded conductors each having a carrying capacity equivalent to not less than No. 14 B. and S. gage, and each covered with an *approved* insulation and covering.

Where not exposed to moisture or severe mechanical injury, each stranded conductor must have a solid insulation at least one thirty-second of an inch in thickness, and must show an insulation resistance between conductors, and between either conductor and the ground, of at least fifty megohms per mile after two weeks' submersion in water at 70 degrees Fahrenheit (21 degrees Centigrade), and be protected by a slow-burning, tough-braided outer-covering.

Where exposed to moisture and mechanical injury (as for use on decks, holds and fire-rooms) each stranded conductor shall have a solid insulation, to be approved, of at least one thirty-second of an inch in thickness and protected by a tough braid. The two conductors shall then be stranded together, using a jute filling. The whole shall then be covered with a layer of flax, either woven or braided, at least one thirty-second of an inch in thickness and treated with a non-inflammable, waterproof compound. After one week's submersion in water at 70 degrees Fahrenheit (21 degrees Centigrade), it must show an insulation between the two conductors, or between either conductor and the ground, of fifty megohms per mile.

93. Bell or Other Wires.

a. Must never be run in same duct with lighting or power wires.

94. Table of Allowable Capacity of Wires.

B. & S. G.	Area Actual C. M.	No. of Strands	Size of Strands B. & S. G.	Amperes.
19	1,288	...	..	...
18	1,624	...	..	3
17	2,048	...	..	...
16	2,583	...	..	6
15	3,257	...	..	...
14	4,107	...	..	12
12	6,530	...	..	17
..	9,016	7	19	21
..	11,368	7	18	25
..	14,336	7	17	30
..	18,081	7	16	35
..	22,799	7	15	40
..	30,856	19	18	50
..	38,912	19	17	60
..	49,077	19	16	70
..	60,088	37	18	85
..	75,776	37	17	100
..	99,064	61	18	120
..	124,928	61	17	145
..	157,563	61	16	170
..	198,677	61	15	200
..	250,527	61	14	235
..	296,387	91	15	270
..	373,737	91	14	320
..	413,639	127	15	340

When greater conducting area than that of 12 B. & S. gage is required, the conductor shall be stranded in a series of 7, 19, 37, 61, 91 or 127 wires, as may be required; the strand consisting of one central wire, the remainder laid around it concentrically, each layer to be twisted in the opposite direction from the preceding.

95. Switchboard.

a. Must be made of non-combustible, non-absorptive, insulating material, such as marble or slate.

b. Must be kept free from moisture, and must be located so as to be accessible from all sides.

c. Must have a main switch, main cut-out and ammeter for each generator.

Must also have a voltmeter and ground detector.

d. Must have a cut-out and switch for each side of each circuit leading from the board.

e. Must be wired with conductors having an insulation as required for moulding or conduit work and covered with a substantial flameproof braid.

96. Resistance Boxes.

(For construction rules, see No. 78.)

a. Must be located on switchboard or away from cumbustible material. When not placed on switchboard they must be mounted on non-inflammable, non-absorptive, insulating material.

97. Switches.

(For construction rules, see No. 65.)

a. When exposed to dampness, they must be enclosed in a water-tight case.

b. Must be of the knife pattern when located on switchboard.

c. Must be provided so that each freight compartment may be separately controlled.

98. Cut-Outs.

(For construction rules, see No. 67.)

a. Must be placed at every point where a change is made in the size of the wire (unless the cut-out in the larger wire will protect the smaller).

b. In such places as upper decks, holds, cargo spaces and fire-rooms, a water-tight and fireproof cut-out may be used, connecting directly to mains when such cut-out supplies circuits requiring not more than 660 watts energy.

c. When placed anywhere except on switchboards must be enclosed in a cabinet lined with fire-resisting material.

d. Except for motors, searchlights and diving lamps must be so placed that no group of lamps, requiring a current of more than 660 watts, shall ultimately be dependent upon one cut-out.

99. Fixtures.

a. Must be mounted on blocks made from well-seasoned lumber treated with two coats of white paint or shellac.

b. Where exposed to dampness, the lamp must be surrounded by a vapor-proof globe.

c. Where exposed to mechanical injury, the lamp must be surrounded by a globe protected by a stout wire guard.

d. Must be wired with same grade of insulation as portable conductors which are not exposed to moisture or mechanical injury.

e. Ceiling fixtures over two feet in length must be provided with stay chains.

100. Sockets.

(For construction rules, see No. 72.)

101. Wooden Mouldings.

(For construction rules, see No. 60.)

a. Where moulding is run over rivets, beams, etc., a backing strip must first be put up and the moulding secured to this.

b. Capping must be secured by brass screws.

102. Interior Conduits.

(For construction rules, see No. 58.)

a. No conduit tube having an internal diameter of less than five-eighths of an inch shall be used. Measurements to be taken inside of metal conduits.

b. Must be continuous from outlet to outlet or to junction boxes, and the conduit must properly enter and be secured to all fittings, and the entire system must be mechanically secured in position.

In case of main runs, this involves running each conduit continuously into a main cut-out cabinet or gutter surrounding the panel board, as the case may be.

c. Must be first installed as a complete conduit system, without the conductors.

d. Must be equipped at every outlet with an *approved* outlet box or plate.

Outlet plates must not be used where it is practicable to install outlet boxes.

The outlet box or plate must be so installed that it will be flush with the finished surface, and if this surface is broken it shall be repaired so that it will not show any gaps or open spaces around the edge of the outlet box or plate.

In vessels already constructed where the conditions are such that neither outlet box nor plate can be installed, these appliances may be omitted by special permission of the Inspection Department having jurisdiction, providing the conduit ends are bushed and secured.

It is suggested that outlet boxes and fittings having conductive coatings be used in order to secure better electrical contact at all points throughout the conduit system.

e. Metal conduits where they enter junction boxes, and at all other outlets, etc., must be provided with *approved* bushings fitted so as to protect wire from abrasion, except when such protection is obtained by the use of *approved* nipples, properly fitted in boxes or devices.

f. Must have the metal of the conduit permanently and effectually grounded.

Conduits must be securely fastened in metal outlet boxes so as to secure good electrical connection. If conduit, couplings, outlet boxes or fittings having protective coating of non-conducting material, such as enamel, are used, such coating must be thoroughly removed from threads of both couplings and conduit and from surfaces of boxes and fittings where the conduit is secured in order to obtain the requisite good connection. Where boxes used for centers of distribution do not afford good electrical connection, the conduits must be bound around them by suitable bond wires. Where sections of metal conduit are installed without being fastened to the metal structure of vessels or grounded metal piping, they must be bonded together and joined to a permanent and efficient ground connection.

Connections to grounded pipes and to conduit must be exposed to view or readily accessible, and must be made by means of approved ground clamps to which the ground wires must be soldered.

Ground wires must be of copper, at least No. 10 B. & S. gage (where largest wire contained in conduit is not greater than No. o B. & S. gage), and need not be greater than No. 4 B. & S. gage (where largest wire contained in conduit is greater than No. o B. & S. gage). They shall be protected from mechanical injury.

g. Junction boxes must always be installed in such a manner as to be accessible.

h. All elbows or bends must be so made that the conduit or lining of same will not be injured. The radius of the curve of the inner edge of any elbow not to be less than three and one-half inches. Must have not more than the equivalent of four-quarter bends from outlet to outlet, the bends at the outlets not being counted.

103. Signal Lights.

a. Must be provided with *approved* telltale board, located preferably in pilot house, which will immediately indicate a burned-out lamp.

104. Motors.

a. Must be wired under the same precautions as with a current of same volume and potential for lighting. The motor and resistance box must be protected by a double-pole cut-out and controlled by a double-pole switch, except in cases where one-quarter horse power or less is used.

The motor leads or branch circuits must be designed to carry a current at least 25 per cent greater than that for which the motor is rated. Where the wires under this rule would be overfused, in order to provide for the starting current, as in the case of many of the alternating current, motors, the wires must be of such size as to be properly protected by these larger fuses.

b. Must be thoroughly insulated. Where possible, should be set on base frames made from filled, hard, dry wood and raised above surrounding deck. On hoists and winches they must be insulated from bed-plates by hard rubber, fiber or similar insulating material.

c. Must be covered with a waterproof cover when not in use.

d. Must each be provided with a name-plate giving maker's name, the capacity in volts and amperes, and the normal speed in revolutions per minute.

105. Insulation Resistance.

The wiring in any vessel must test free from grounds; *i. e.*, the complete installation must have an insulation between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.), of not less than the following:—

Up to 25 amperes	....	800,000 ohms.
Up to 50 amperes	....	400,000 ohms.
Up to 100 amperes	....	200,000 ohms.
Up to 200 amperes	....	100,000 ohms.
Up to 400 amperes	....	50,000 ohms.
Up to 800 amperes	....	25,000 ohms.
Up to 1,600 amperes	....	12,500 omhs.

All cut-outs and safety devices in place in the above.

Where lamp sockets, receptacles and electroliers, etc., are connected, one-half of the above will be required.

USEFUL INFORMATION.

RESUSCITATION FROM ELECTRIC SHOCK.

Rules Recommended by

COMMISSION ON RESUSCITATION FROM ELECTRIC SHOCK

Representing

The American Medical Association
The National Electric Light Association
The American Institute of Electrical Engineers

Dr. W. B. Cannon, Chairman; Professor of Physiology, Harvard University.
Dr. Yandell Henderson, Professor of Physiology, Yale University.
Dr. S. J. Meltzer, Head of Department of Physiology and Pharmacology, Rockefeller Institute for Medical Research.
Dr. Edw. Anthony Spitzka, Director and Professor of General Anatomy, Daniel Baugh Institute of Anatomy, Jefferson Medical College.
Dr. George W. Crile, Professor of Surgery, Western Reserve University.
W. C. L. Eglin, Past-President National Electric Light Association.
Dr. A. E. Kennelly, Professor of Electrical Engineering, Harvard University.
Dr. Elihu Thomson, Electrician, General Electric Company.
W. D. Weaver, Secretary; Editor Electrical World.

Follow These Instructions Even if Victim Appears Dead.

I. IMMEDIATELY BREAK THE CIRCUIT.

With a single quick motion, free the victim from the current. Use any *dry non-conductor* (clothing, rope, board) to

Inspiration; Pressure Off.

Figure 206.

move either the victim or the wire. Beware of using metal or any moist material. While freeing the victim from the live conductor have every effort also made to shut off the current quickly.

II. INSTANTLY ATTEND TO THE VICTIM'S BREATHING.

1. As soon as the victim is clear of the conductor, rapidly feel with your finger in his mouth and throat and remove any foreign body (tobacco, false teeth, etc.) Then *begin artificial respiration at once*. Do not stop to loosen the victim's clothing now; *every moment of delay is serious*. Proceed as follows:

a. Lay the subject on his belly, with arms extended as straightforward as possible and with face to one side, so that nose and mouth are free for breathing (see Fig. 206). Let an assistant draw forward the subject's tongue.

b. Kneel straddling the subject's thighs and facing his head; rest the palms of your hands on the loins (on the muscles of the small of the back), with fingers spread over the lowest ribs, as in Fig. 206.

c. With arms held straight, swing forward slowly so that the weight of your body is gradually, but *not violently*, brought to bear upon the subject (see Fig. 207). This act should take from two to three seconds.

Immediately swing backward so as to remove the pressure, thus returning to the position shown in Fig. 206.

d. Repeat deliberately twelve to fifteen times a minute the swinging forward and back—a complete respiration in four or five seconds.

e. As soon as this artificial respiration has been started, and while it is being continued, an assistant should loosen any tight clothing about the subject's neck, chest or waist.

Expiration; Pressure On.

Figure 207.

2. Continue the artificial respiration (if necessary, at least an hour), *without interruption,* until natural breathing is restored, or until a physician arrives. If natural breathing stops after being restored, use artificial respiration again.

3. *Do not give any liquid by mouth until the subject is fully conscious.*

4. Give the subject fresh air, but keep him warm.

III. SEND FOR NEAREST DOCTOR AS SOON AS ACCIDENT IS DISCOVERED.

PRACTICAL HINTS.

A full description of the Wheatsone bridge, the telephone, magneto and other instruments, as well as the many ways of their application in testing for defects and for circuits in electrical installations having been given in a previous work of the authors (*Wiring Diagrams* and *Descriptions*) it is not thought necessary to repeat them here, especially as a work of this kind is necessarily limited in diagrams which would be required to a full understanding of methods. This chapter will, therefore, consist only of such hints and instructions as apply to general work.

An electric light circuit may be tested for "short circuit" by connecting an incandescent lamp in place of one of the fuses. If the lamp burns while there are no lamps in circuit, there is sure to be a short circuit. A low candle-power lamp will indicate with less current than a high-candle-power lamp and is, therefore, better. If no lamp is available a small fuse should first be tried.

A test for "ground" may be made in the same way, but the lamp must be connected to both sides in turn and the fuse left out. If the main system to which the circuit to be tested connects is not grounded, a temporary ground must be put on. This is best done by connecting a lamp with one wire to a gas or water pipe and the other to the "live" binding screw on the opposite side of cutout to that in which the other lamp is connected. Thus, in Figure 208, if a ground should exist at 3 and

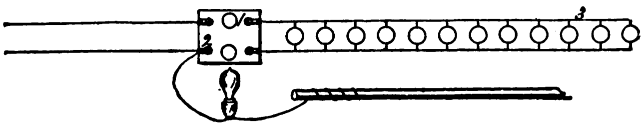


Figure 208.

the lamp be connected to gas pipe, as shown, the test lamp at 1 would burn.

If a voltmeter were connected in place of either of the lamps, the test would be much more searching.

With 3-wire systems no ground need be put on, as the neutral wire will always be found grounded. The lamp need be tried in the outside fuses only. This test will be more searching if lamps are placed in all sockets connected.

In placing fuses in the 3-wire, 110-220 volt system, the neutral wire should always be fused first.

By reference to Figure 209 it will be seen that while the neutral fuse in main blocks *a* is out, the two circuits of lamps *c* and *d* must burn in series; that is, just as much current must pass through one circuit as through the other. So long as there is an equal number of lamps in each circuit there is no trouble; but should most of the lamps in one circuit be turned off, those remaining would have to carry all the current that passes through the lamps of the other circuit. This current would overheat them and break, or burn them cut in a very short time. If the neutral fuse is in place, each circuit is independent of the other and the neutral wire only carries the difference in current between the two sets of lamps. In order to insure against a neutral fuse "blowing" first in case of trouble, it is generally made heavier than in the outside wires. When a 3-wire circuit is to be cut off, the outside fuses should be drawn first.

In order to find which is the "neutral" wire, two 110 volt lamps are connected in series and the wires from them brought in contact with two of the three wires. If both lamps burn at full candle power we have 220 volts, which is the pressure of the outside wires, and, therefore, the other wire must be the

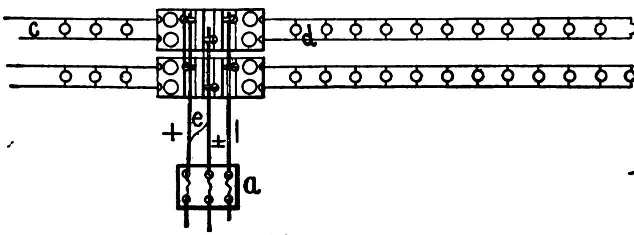


Figure 209.

neutral. If the lamps burn only at half candle power, we have only 110 volts and one of the wires must be the neutral. That wire which gives 110 volts with either one of the other two wires is the neutral; this wire should always be run in the center between the other two.

A test for the neutral wire can also be made by connecting a lamp to ground. A lamp connected this way will burn from either of the outside wires, but not from the neutral.

If the neutral wire should be connected to any but the middle binding post of 3-wire cutouts and the outside wire made. (See Section 1.)

to the other two, one-half of the lamps would be almost immediately destroyed, being subject to 220 volts, while the other half would burn properly.

If a short circuit occurs, say at *e*, Figure 209, on one side of a 3-wire system and blows the neutral fuse on that side of the circuit, we shall have 220 volts on the lamps on the opposite side. This will quickly burn them out. Most of these troubles are avoided to some extent by the use of such branch cutouts as shown. This confines trouble of this kind to the mains.

On any system having a neutral wire or a wire on one side grounded, if a ground on either of the other wires occurs, the trouble can be temporarily remedied by simply changing the two wires of that circuit at the cutout. This will transfer the ground to the side already grounded, so that it will not interfere with operation. The ground must, however, be cleared up at once as no grounding is ever allowed inside of any building.

When strip cutouts are set horizontally and there is no bridge between opposite polarities, there will be the possibility of a partially melted upper fuse sagging down and forming a short circuit.

On panel boards where fuses are set too close together, the heat of one fuse while blowing will often blow the next fuse above it.

If large fuses are enclosed in small and very tight cabinets, the vapors formed by blowing will often cause short circuits.

Before installing fuses in a "loaded" circuit, it is advisable to disconnect as many lights and other devices as possible. If there is a main switch this can easily be done. If there is no such switch on that part of the system, the task of placing fuses is somewhat hazardous; for at the very instant that the second fuse touches its terminal a great rush of current will flow. If there happens to be a "short" on the line both fuses will probably blow and may burn the operator's hands and face severely. In order to avoid this, extremely careful manipulation is necessary. The first fuse can be placed without any difficulty, as there will be no current flow unless the circuits are grounded. Before attempting to place the second fuse the circuits may be tested for "shorts" by placing a "jumper" (a piece of wire heavy enough so that it will not be heated by the current it is to carry) with the ends on the other fuse terminals. This "jumper" will complete the circuit and, if all is in order the lights will burn. If there are two men, one may hold the jumper while the other places the fuse, but it should be placed as quickly as possible, especially if the circuit has a motor load, for these will be started very soon after the lights come on and will greatly increase the current. If there is but one man the jumper may be temporarily fastened to the mains.

A jumper is not absolutely necessary even with large fuses, for if the last contact is made quickly and held steady, there will be very little arcing; one should, however, provide all protection possible. If a piece of asbestos is at hand, it may be used to cover the fuses, so as to protect the hands and face from melted metal.

Before attempting to re-fuse a circuit, note condition of cutout block. If there is evidence of a great flash, it is very likely that the fuse was blown by a short circuit. If the blowing was caused by a slight overload or loose contact, the destructive effect will be much less.

Much trouble can be prevented by cleaning terminals of fuse blocks occasionally and going over nuts and screws to see that they are tight.

In Figure 210, *a* shows the proper way of connecting small wires into such terminals. This method prevents the screw from cutting into the main wire and allowing it to break.

A wire should always be bent around the binding post of switch or cutout in the direction in which the nut which is to hold it must turn to be fastened as in *c*. If a wire is not long enough to be bent around the post or screw, a small piece of wire should be placed opposite it so as to give a level bearing to nut or washer. See *b*.

Plug cutouts having their metal parts projecting above the porcelain, as shown at d, should be connected, whenever pos-

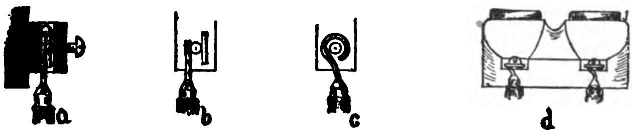


Figure 210.

sible, so that these metal parts are dead when fuses are withdrawn. This will prevent many accidental short circuits.

The positive and negative wires of a circuit can easily be determined by immersing both wires in a little water, keeping them an inch or so apart. Small bubbles will soon appear at the negative wire.

If an arc lamp has been properly connected, the upper carbon will be heated much more than the lower and will remain red longer. An arc lamp improperly connected is said to be burning "upside down" and will at once manifest itself by the strong light thrown against the ceiling.

It is very often found necessary to determine the capacity of a cable which is already installed and where it is impossible to get at the separate wires of which it is formed. As cables are usually made up in a uniform manner, as shown in the table below, their capacity can be determined by the following method: To find the number of circular mils in a cable made up of wires of uniform size. Measure diameter of cable, count number of wires in outside layer, and, referring to the table below, find the same number in the first column; divide the diameter of cable by the number set opposite this in the second column. This will give the diameter of each wire. Multiply this diameter by itself and then by the number of wires contained in cable as given in the third column. All measurements should be expressed in mils (1/1,000 inch) and the result will be the circular mils contained in cable.

Outside layer	6 wires	3 times diameter	7 wires in cable
Outside layer	12 wires	5 times diameter	19 wires in cable
Outside layer	18 wires	7 times diameter	37 wires in cable
Outside layer	24 wires	9 times diameter	61 wires in cable
Outside layer	30 wires	11 times diameter	91 wires in cable
Outside layer	36 wires	13 times diameter	127 wires in cable
Outside layer	42 wires	15 times diameter	169 wires in cable

The various figures in Figure 211 are designed to show how many single wires may be run in one conduit. Under each figure is given a number which, if multiplied by the diameter of the wire to be used will give the smallest diameter of tube which can contain the corresponding number of wires. Thus, for instance, if 12 wires are run through one tube or conduit, the diameter of that conduit must be at least 4 1/3 times as great as the diameter of the wire to be used. Each figure illustrates the amount of spare room the corresponding number of wires leave, and it is necessary to use considerable judgment. Long runs will require more space, especially if the wires be quite large. Much also depends upon the nature of the insulation and the temperature. The figures are believed to be correct for single wires and can be followed for twin wires, as the same number of conductors arranged that way will not occupy as much space as single wires. The actual diameter of lined and unlined conduits are given in another table and may be referred to. The best way to accurately determine the diameter of small wire consists in cutting a number of short pieces and laying them together, then measuring over all and dividing the measurement by the number of wires.

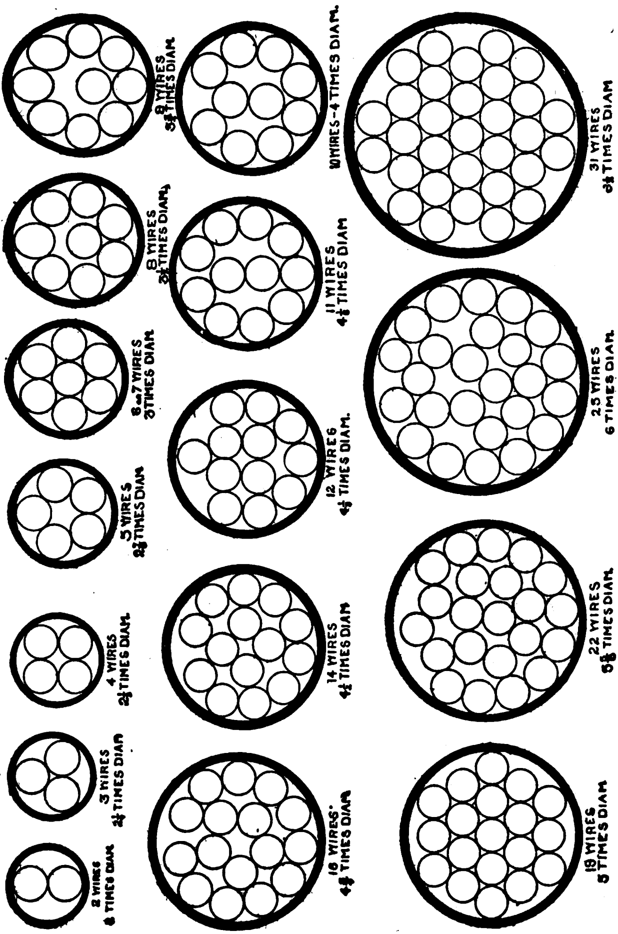

9 WIRES
10 WIRES-4 TIMES DIAM.
31 WIRES
8 WIRES
11 WIRES
6 & 7 WIRES
3 TIMES DIAM.
25 WIRES
6 TIMES DIAM.
5 WIRES
12 WIRES
22 WIRES
4 WIRES
14 WIRES
3 WIRES
2 WIRES
16 WIRES
19 WIRES
5 TIMES DIAM

Figure 211.

TRICKS OF THE TRADE.

Cases have been known where it was requested to replace single pole switches by double pole, that the single pole switch was replaced as requested, but, instead of running both wires through it as required, only one wire had been properly brought into it and the other two binding posts filled out with short pieces of wire calculated to deceive the inspector. A test to detect this without disconnecting the swtich is easily made. By reference to Figure 212 it will be seen that if a double pole snap switch is properly connected, current can be felt if the points *a* and *b* are touched with moistened fingers. If the switch is connected single pole, current can be felt at *b* and *c*, when the switch is open, only.

On one occasion a wireman had run some wires on insulators along a ceiling and instead of soldering joints had care-

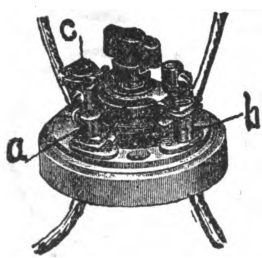


Figure 212.

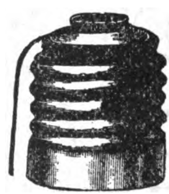


Figure 213.

fully, in many places above the joints, smoked the ceiling with a candle in order to deceive an inspector.

In several cases where an "over-all" test of insulation resistance was made, meter loops which had been run in continuous pieces were found with the wire "nicked" with a knife and then broken, leaving the insulation nearly intact, but the circuit open. A similar trick is often worked with the ground wire of ground detectors.

In other cases plugs with fuses removed were put in "bad" circuits. In one case the real circuit wires (concealed work) were disconnected from cutouts and pushed back into the wall and short pieces connected instead.

In another case where wire not up to requirements had been used and condemned, this wire, being run between joists and concealed by plastering, was pushed back and short pieces of approved wire stuck in at outlets.

Sometimes in fished work after inspection the long pieces of loom reaching from outlet to outlet are withdrawn and short pieces at the outlets substituted.

Lamp butts with wire terminals twisted together, or a strand of wire from lamp cord twisted around the base as shown in Figure 213 and screwed into the cutout are often used in place of fuses. The strand of cord is sometimes used to help out a fuse plug on an overloaded circuit.

METER CONNECTIONS.

Figures 214 to 216 show method of making meter connections in apartment buildings. Figure 214 shows connections for apartments where only one circuit is used for each apartment. In this case the meter is connected in the branch circuits after they leave their respective cutout blocks. While only three meters are shown in the figure any number of apartments could be connected in the same manner.

Figures 215 and 216 show connections where two or more circuits are used in each apartment. Each meter leg is fused where it connects to the mains. After leaving the meter the main feeding the apartment is carried to the branch cutout blocks of which there can be any number. The design shown in Figure 216 is especially applicable to apartment buildings as a number of meters can be placed in a location where there is little head room as in the ordinary basement.

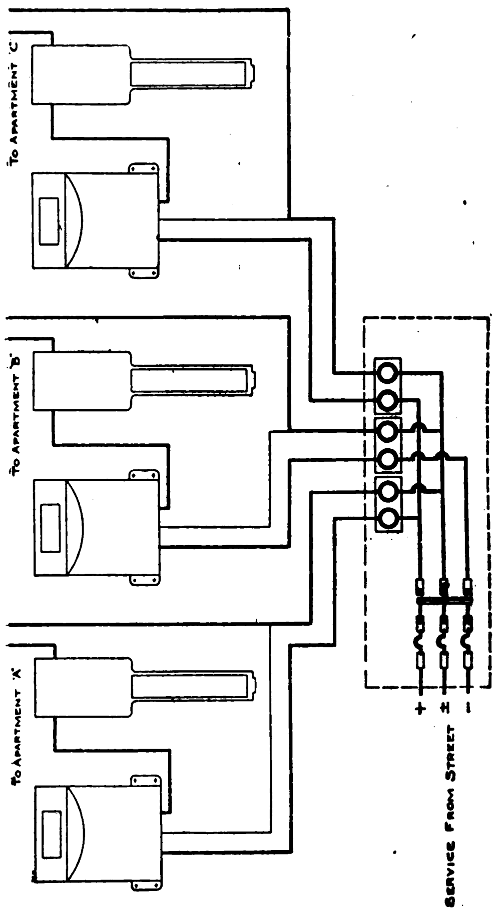

To Apartment 'C'
To Apartment 'B'
To Apartment 'A'
+
±
−
Service From Street

Figure 214.

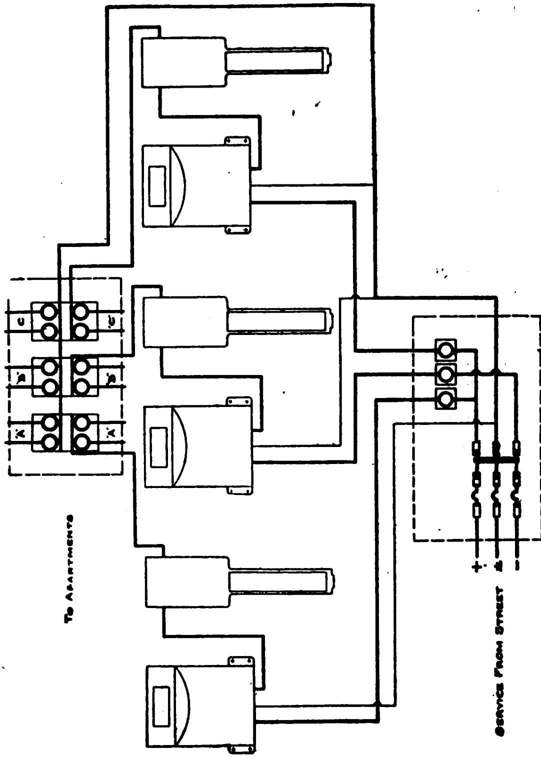


Figure 215.

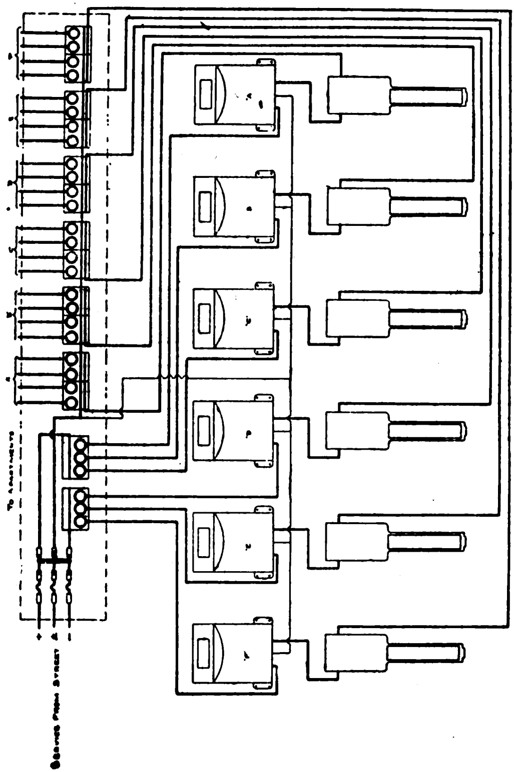


Figure 216.

Table of Carrying Capacity of Wires.

The following table, showing the allowable carrying capacity of copper wires and cables of ninety-eight per cent conductivity, according to the standard adopted by the American Institute of Electrical Engineers, must be followed in placing interior conductors.

For insulated aluminum wire the safe carrying capacity is eighty-four per cent of that given in the following tables for copper wire with the same kind of insulation.

TABLE NO. I.

B. & S. G.	Table A. Rubber Insulation. Amperes.	Table B. Other Insulations. Amperes.	Circular Mils.
18	3	5	1,624
16	6	8	2,583
14	12	16	4,107
12	17	23	6.530
10	24	32	10,380
8	33	46	16,510
6	46	65	26,250
5	54	77	33,100
4	65	92	41,740
3	76	110	52,630
2	90	131	66,370
1	107	156	83,690
0	127	185	105,500
00	150	220	133,100
000	177	262	167,800
0000	210	312	211,600
Circular Mils.			
200,000	200	300	
300,000	270	400	
400,000	330	500	
500,000	390	590	
600,000	450	680	
700,000	500	760	
800,000	550	840	
900,000	600	920	
1,000,000	650	1,000	
1,100,000	690	1,080	
1,200,000	730	1,150	
1,300,000	770	1,220	
1,400,000	810	1,290	
1,500,000	850	1,360	
1,600,000	890	1,430	
1,700,000	930	1,490	
1,800,000	970	1,550	
1,900,000	1,010	1,610	
2,000,000	1,050	1,670	

The lower limit is specified for rubber-covered wires to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the above tables.

WIRING TABLES.

The wiring tables, II-VI, are arranged in the following manner: For each size of wire and voltage considered there is given (under the proper voltage and opposite the number of the wire under the heading B. & S.) the distance it will carry 1 ampere at a loss designated at top of page.

The same wire will carry 2 amperes only half as far at the same percentage of loss and again will carry 1 ampere twice as far at double the percentage of loss.

From these facts we deduce the rule of these tables, which is: Multiply the distance in feet (one leg only) by the number of amperes to be carried. Take the number so obtained and under the proper voltage find the number nearest equal to it. Opposite this number, under the heading B. & S., will be found the size of wire required. To illustrate: We have 22 amperes to carry a distance of 135 feet and the loss to be allowed is 3 per cent at 110 volts. We therefore multiply 135 × 22 = 2970, and turning to table IV, which is figured for 3 per cent loss, follow downward in the column under 110 until we reach the number nearest equal to 2970, which, in this case, is .3180 corresponding to a No. 7 wire. With this wire our loss will be slightly less than 3 per cent, while with No. 8 it would be somewhat in excess of 3 per cent.

For three-wire systems using 110 volts on each side the column marked 220 volts should be used. The column marked 440 volts is provided for three-wire systems using 220 volts on each side. The sizes determined will be correct for all three wires in both cases.

The columns at the right, marked motors, are arranged in the same way, the only difierence being, for greater convenience, they are figured in horse-power feet instead of ampere feet. For this reason we multiply the distance in feet by the number of horse-power to be transmitted and divide by the percentage of loss, all other operations remaining the same as under lights. When any considerable current is to be carried only a short distance the wire indicated by the desired loss will very likely not have sufficient carrying capacity; it is, therefore, always necessary to consult the table of carrying capacities.

RULE FOR WIRING TABLES.

For lights, find the ampere feet (one leg) and under the proper voltage find the number equal to this or the next larger; opposite this number, in the column marked B. & S., will be found the size of wire required.

For motors, proceed in the same way, using horse-power feet instead of ampere feet.

For alternating currents, the results obtained by multiplying the amperes (or horse-power) by the feet, should be multiplied by the following factors:

1.1 for single-phase systems, all lights.

1.5 for single-phase systems, all motors.

For two-phase, four-wire, or three-phase, three-wire systems, each wire need be only one-half as large as for single-phase systems and the number obtained may, therefore, be divided by two.

TABLE II.—WIRING TABLE FOR 1% LOSS.

Lights in Amperes. Voltage.				B. & S. Gauge	Car. Cap.	Motors in H. P. Voltage.				Resis. per foot.
52	110	220	440			110	220	440	500	
98	209	418	836	14	12	28	112	448	579	.002628
124	263	526	1052	13	.....	35	140	560	724	.002084
158	333	666	1332	12	17	44	176	704	910	.001653
200	420	840	1680	11	.....	56	224	896	1159	.001311
250	529	1058	2116	10	24	70	280	1120	1449	.001040
314	665	1330	2660	9	.....	88	352	1408	1821	.000824
397	841	1682	3364	8	33	112	448	1792	2318	.000654
501	1060	2120	4240	7	.....	141	564	2256	2918	.000519
634	1338	2676	5352	6	46	178	712	2848	3684	.000411
798	1687	3374	6748	5	54	224	896	3584	4636	.000326
1000	2124	4248	8496	4	65	283	1132	4528	5858	.000259
1271	2683	5366	10732	3	76	357	1428	5712	7389	.000205
1595	3374	6748	13496	2	90	449	1796	7184	9294	.000163
2011	4264	8527	17054	1	107	568	2272	9088	11757	.000129
2543	5392	10784	21568	0	127	718	2872	11488	14762	.000102
3228	6790	13580	27160	00	150	905	3620	14480	18733	.000081
4053	8594	17188	34376	000	177	1145	4580	18320	23701	.000064
5090	10784	21568	43136	0000	210	1437	5748	22992	29745	.000051
6032	12790	25580	51160	250000	235	1696	6784	27136	35107	.0000431
7222	15277	30554	61108	300000	270	2036	8144	32576	42145	.000036
8441	17857	35714	71428	350000	300	2368	9472	37888	49017	.0000308
9629	20370	40740	81480	400000	330	2714	10856	43424	56179	.000027
10833	22916	45832	91664	450000	360	3054	12216	48864	63217	.000024
12093	25581	51162	102324	500000	390	3393	13572	54288	70235	.0000215
24074	50925	101850	203700	1000000	650	6786	27144	108576	140470	.0000108
48148	101851	203702	407404	2000000	1050	13573	54292	217168	280961	.0000054

TABLE III.—WIRING TABLE FOR 2% LOSS.

Lights in Amperes.				B. & S. Gauge	Car. Cap.	Motors in H. P.				Resis. per foot.
Voltage.						Voltage.				
52	110	220	440			110	220	440	500	
196	418	836	1672	14	12	56	224	896	1158	.002628
248	526	1052	2104	13	.....	70	280	1120	1448	.002084
316	666	1332	2664	12	17	88	352	1408	1820	.001653
400	840	1680	3360	11	.....	112	448	1792	2318	.001311
500	1058	2116	4232	10	24	140	560	2240	2898	.001040
628	1330	2660	5320	9	.....	176	704	2816	3642	.000824
794	1682	3364	6728	8	33	224	896	3584	4636	.000654
1002	2120	4240	8480	7	.....	282	1128	4512	5836	.000519
1268	2676	5352	10704	6	46	356	1424	5696	7368	.000411
1596	3374	6748	13496	5	54	448	1792	7168	9272	.000326
2000	4248	8496	16992	4	65	566	2264	9056	11716	.000259
2542	5366	10732	21464	3	76	714	2856	11424	14778	.000205
3190	6748	13496	26992	2	90	898	3592	14368	18588	.000163
4022	8528	17054	34108	1	107	1136	4544	18176	23514	.000129
5086	10784	21568	43136	0	127	1436	5744	22976	29524	.000102
6456	13580	27160	54320	00	150	1810	7240	28960	37466	.000081
8106	17188	34376	68752	000	177	2290	9160	36640	47402	.000064
10180	21568	43136	86272	0000	210	2874	11496	45984	59490	.000051
12064	25580	51160	102320	250000	235	3392	13568	54272	70214	.0000431
14444	30554	61108	122216	300000	270	4072	16288	65152	84290	.000036
16882	35714	71428	142856	350000	300	4736	18944	75776	98034	.0000308
19258	40740	81480	162960	400000	330	5428	21712	86848	112358	.000027
21666	45832	91664	183328	450000	360	6108	24432	97728	126434	.000024
24186	51162	102324	204648	500000	390	6786	27144	108576	140470	.0000215
48148	101850	203700	407400	1000000	650	13572	54288	217152	280940	.0000108
96296	203702	407404	814808	2000000	1050	27146	108584	434336	561922	.0000054

TABLE IV.—WIRING TABLE FOR 3% LOSS.

Lights in Amperes.				B. & S. Gauge.	Car. Cap.	Motors in H. P.				Resis. per foot.
Voltage.						Voltage.				
52	110	220	440			110	220	440	500	
294	627	1254	2508	14	12	84	336	1344	1737	.002628
372	789	1578	3156	13	.....	105	420	1680	2172	.002084
474	999	1998	3996	12	17	132	528	2112	2730	.001653
600	1260	2520	5040	11	.....	168	672	2688	3477	.001311
750	1587	3174	6348	10	24	210	840	3360	4347	.001040
942	1995	3990	7980	9	.....	264	1056	4224	5463	.000824
1191	2523	5046	10092	8	33	336	1344	5376	6954	.000654
1503	3180	6360	12720	7	.....	423	1692	6768	8754	.000519
1902	4014	8028	16056	6	46	534	2136	8544	11052	.000411
2394	5061	10122	20244	5	54	672	2688	10752	13808	.000326
3000	6372	12744	25488	4	65	849	3396	13584	17574	.000259
3813	8049	16098	32196	3	76	1071	4284	17136	22167	.000205
4785	10122	20244	40458	2	90	1347	5388	21552	27882	.000163
6033	12792	25581	51162	1	107	1704	6816	27264	35271	.000129
7629	16176	32352	64704	0	127	2154	8616	34464	44286	.000102
9684	20370	40740	81480	00	150	2715	10860	43440	56199	.000081
12059	25782	51564	103128	000	177	3435	13740	54960	71103	.000064
15270	32352	64704	129408	0000	210	4311	17244	68976	89235	.000051
18096	38370	76740	153480	250000	235	5088	20352	81408	105321	.0000431
21666	45831	91662	183324	300000	270	6108	24432	97728	126435	.000036
25323	53571	107142	214284	350000	300	7104	28416	113664	147051	.0000308
28887	61110	122220	244440	400000	330	8142	32568	130372	168537	.000027
32499	68748	137496	274992	450000	360	9162	36648	146592	189651	.000024
36279	76743	153486	306972	500000	390	10179	40716	162864	210705	.0000215
72222	152775	305550	611100	1000000	650	20358	81432	325728	421410	.0000108
144444	305553	611106	1222212	2000000	1050	40719	162876	651504	842883	.0000054

TABLE V.—WIRING TABLE FOR 4% LOSS.

Lights in Amperes. Voltage.				B. & S. Gauge.	Car. Cap.	Motors in H. P. Voltage.				Resis. per foot.
52	110	220	440			110	220	440	500	
392	836	1672	3344	14	12	112	448	1792	2316	.002628
496	1052	2104	4208	13	.....	140	560	2240	2896	.002084
632	1332	2664	5328	12	17	176	704	2816	3640	.001653
800	1680	3360	6720	11	.....	224	896	3584	4636	.001311
1000	2116	4232	8464	10	24	280	720	4480	5796	.001040
1256	2660	5320	10640	9	.....	352	1408	5632	7284	.000824
1588	3364	6728	13456	8	33	448	1792	7168	9272	.000654
2004	4240	8480	16960	7	.....	562	2256	9024	11672	.000519
2536	5352	10704	21408	6	46	712	2848	11392	14736	.000411
3192	6748	13496	26992	5	54	896	3584	14336	18544	.000326
4000	8496	16992	33984	4	65	1132	4528	18112	23432	.000259
5084	10732	21464	42928	3	76	1428	5712	22848	29556	.000205
6380	13496	26992	53984	2	90	1796	7184	28736	37176	.000163
8044	17054	34108	68216	1	107	2272	9088	36352	47028	.000129
10172	21568	43136	86272	0	127	2872	11488	45952	59048	.000102
12912	27160	54320	108640	00	150	3620	14480	57920	74932	.000081
16212	34376	68752	137504	000	177	4580	18320	73280	94804	.000064
20360	43136	86272	172544	0000	210	5748	22992	91968	118980	.000051
24128	51160	102320	204640	250000	235	6784	27136	108544	140428	.0000431
28888	61108	122216	244432	300000	270	8144	32576	130304	168580	.000036
33764	71428	142856	285712	350000	300	9472	37888	151552	196068	.0000308
38516	81480	162960	325920	400000	330	10856	43424	173696	224716	.000027
43332	91664	183328	366656	450000	360	12216	48864	195456	252868	.000024
48372	102324	204648	409296	500000	390	13572	54288	217152	280940	.0000215
96296	203700	407400	814800	1000000	650	27144	108576	434304	561880	.0000108
192592	407404	818808	1629616	2000000	1050	54292	217168	868672	1123844	.0000054

TABLE VI.—WIRING TABLE FOR 5% LOSS.

Lights in Amperes.				B. & S. Gauge.	Car. Cap.	Motors in H. P.				Resis. per foot.
Voltage.						Voltage.				
52	110	220	440			110	220	440	500	
490	1045	2090	4180	14	12	140	560	2240	2895	.002628
620	1315	2630	5260	13	.....	175	700	2800	3620	.002084
790	1665	3330	6660	12	17	220	880	3520	4550	.001653
1000	2100	4200	8400	11	.....	280	1120	4480	5795	.001311
1250	2645	5290	10580	10	24	350	1400	5600	7245	.001040
1570	3325	6650	13300	9	.....	440	1760	7040	9105	.000824
1985	4205	8410	16820	8	33	560	2240	8960	11590	.000654
2505	5300	10600	21200	7	.....	705	2820	11280	14590	.000519
3170	6690	13380	26760	6	46	890	3560	14240	18420	.000411
3990	8435	16870	33740	5	54	1120	4480	17920	23180	.000326
5000	10620	21240	42480	4	65	1450	5660	22640	29290	.000259
6355	13415	26830	53660	3	76	1785	7140	28560	36945	.000205
7975	16870	33740	67480	2	90	2245	8980	35920	46470	.000163
10055	21320	42635	85270	1	107	2840	11360	45440	58785	.000129
12715	26960	53920	107840	0	127	3590	14360	57440	73810	.000102
16140	33950	67900	135800	00	150	4525	18100	72400	93665	.000081
20265	42970	85940	171880	000	177	5725	22900	91600	118505	.000064
25450	53920	107840	215680	0000	210	7185	28740	114960	148725	.000051
30160	63950	127900	255800	250000	235	8480	33920	135680	175535	.0000431
36110	76385	152770	305540	300000	270	10180	40720	162880	210725	.000036
42205	89285	176570	357140	350000	300	11840	47360	189440	245085	.0000308
48145	101850	283700	407400	400000	330	13570	54280	217120	280895	.000027
54165	114580	229160	458320	450000	360	15270	61080	244320	316085	.000024
60465	127905	255810	511620	500000	390	16965	67860	271440	351175	.0000215
120370	254625	509250	1018500	1000000	650	33930	135720	542880	702350	.0000108
240740	509255	1018510	2037020	2000000	1050	67865	271460	1085640	1404805	.0000054

It is often necessary to reinforce mains which have become overloaded. It is quite usual though often very incorrect, to choose by the table of carrying capacities a wire of such size that the rated capacity of it and the wire to be re-enforced shall be equal to the load. Small wires have proportionately a much greater radiating surface than larger ones and therefore their carrying capacity is proportionally greater. In order that a wire connected in parallel with another wire shall carry a certain current, its circular mils, must be equal $\frac{C.M. \times a}{A}$ where C. M. stands for the cross-section of the larger wire in circular mils and A for the current to be carried by it, while a is the current to be carried by the extra wire. Table No. VII is calculated from this rule and shows the size of wire necessary to re-enforce another overloaded to a certain per cent as indicated in the top row. For instance, a 0000 wire overloaded 40 per cent requires re-enforcement by a No. 1; a No. 3 wire overloaded 20 per cent requires a No. 10 wire. Where large wires are re-enforced in this way by smaller ones great care must be taken that the larger wire cannot be accidentally broken or disconnected, since in such a case the whole load would be forced over the smaller wire and would likely result in a fire. The two wires should be securely soldered together.

TABLE NO. VII.

Amperes.	B. & S.	10%	20	30	40	50	60	70	80	90	100
210	0000	6	4	2	1	0	00	000	000	0000	0000
177	000	8	5	3	2	1	0	00	000	000	000
150	00	9	6	4	3	2	1	0	0	00	00
127	0	10	7	5	4	3	2	1	1	0	0
107	1	10	8	6	5	4	3	2	2	1	1
90	2	11	9	7	6	5	4	3	3	2	2
76	3	12	10	8	7	6	5	4	4	3	3
65	4	14	11	9	8	7	6	5	5	4	4

INDIVIDUAL SWITCHES AND OUT-OUTS.

	125 Volts or less		126-250 Volts		
	Minimum Separation of Opposite Polarity	Minimum Break Distance	Minimum Separation of Opposite Polarity	Minimum Break Distance	
10 Amperes or less	1 inch	¾ inch	1½ inch	1¼ inch	NOTE. — For spacings or Edison three-wire systems, see note to Rule 51*k*.
11-35 Amperes	1¼ "	1 "	1¾ "	1½ "	
36-100 "	1½ "	1¼ "	2¼ "	2 "	
101-300 "	2¼ "	2 "	2½ "	2¼ "	
301-600 "	2¾ "	2½ "	2¾ "	2½ "	
601-1000 "	3 "	2¾ "	3 "	2¾ "	
FUSES					
10 Amperes or less.	¾ "	¾ "	1½ "	1¼ "	
11-100 Amperes	1 "	¾ "	1¾ "	1¼ "	
101-300 "	1 "	1 "	2 "	1½ "	
301-1000 "	1¼ "	1¼ "	2½ "	2 "	

PANEL BOARDS CONTAINING SWITCHES OR STRIP FUSES.

	125 Volts or less			126-250 Volts	
	Minimum Separation of Opposite Polarity	Minimum Break Distance		Min. Sep. of Op. Polarity	Minimum Break Distance
10 Amperes or less	¾ inch	½ inch	10 Amperes or less	1½ inch	1¼ inch
11-25 Amperes...........	1 "	¾ "	11-35 Amperes...	1¾ "	1½ "
26-50 "	1¼ "	1 "	36-100 "	2¼ "	2 "
FUSES					
10 Amperes or less	¾ "	¾ "	10 Amperes or less	1½ "	1¼ "
11-100 Amperes	1 "	¾ "	11-100 Amperes ..	1¾ "	1¼ "
Separation of Strip Fuses–Same Polarity	½ inch			¾ inch	

PANEL BOARDS WITH ENCLOSED FUSES—NO SWITCHES.

	125 Volts or less	126-250 Volts	
Separation of Branch Bars..	¾ inch	1¼ inch	
Separation Between Main and Branch Bars	½ "	¾ "	

DIMENSIONS OF COPPER WIRE

Numbers B. & S. Gauge	Diameters in Mils.	Areas in circular Mils. C.M.—d²	Weights		Ohms per 1000 feet
			1000 feet	Mile	
0000	460.	211,600.	641.	3,382.	.051
000	410.	168,100.	509.	2,687.	.064
00	365.	133,225.	403.	2,129.	.081
0	325.	105,625.	320.	1,688.	.102
1	289.	83,521.	253.	1,335.	.129
2	258.	66,564.	202.	1,064.	.163
3	229.	52,441.	159.	838.	.205
4	204.	41,616.	126.	665.	.259
5	182.	33,124.	100.	529.	.326
6	162.	26,244.	79.	419.	.411
7	144.	20,736.	63.	331.	.519
8	128.	16,384.	50.	262.	.654
9	114.	12,996.	39.	208.	.824
10	102.	10,404.	32.	166.	1.040
11	91.	8,281.	25.	132.	1.311
12	81.	6,561.	20.	105.	1.653
13	72.	5,184.	15.7	83.	2.084
14	64.	4,096.	12.4	65.	2.628
15	57.	3,249.	9.8	52.	3.314
16	51.	2,601.	7.9	42.	4.179
17	45.	2,025.	6.1	32.	5.269
18	40.	1,600.	4.8	25.6	6.645
19	36.	1,296.	3.9	20.7	8.617
20	32.	1,024.	3.1	16.4	10.566
21	28.5	812.3	2.5	13.	13.283
22	25.3	640.1	1.9	10.2	16.85
23	22.6	510.8	1.5	8.2	21.10
24	20.1	404.	1.2	6.5	26.70
25	17.9	320.4	.97	5.1	33.67
26	15.9	252.8	.77	4.	42.68
27	14.2	201.6	.61	3.2	53.52
28	12.6	158.8	.48	2.5	67.84
29	11.3	127.7	.39	2.	84.49
30	10.	100.	.3	1.6	107.3
31	8.9	79.2	.24	1.27	136.2
32	8.	64.	.19	1.02	168.5
33	7.1	50.4	.15	.81	214.0
34	6.3	39.7	.12	.63	271.7
35	5.6	31.4	.095	.5	343.6
36	5.	25.	.076	.4	431.6

Table giving the outside diameters of rubber covered wires for use on voltages less than 600.

Size B. & S Gauge	Solid Wire Single Braid	Solid Wire Double Braid	Strand-ed Wire Single Braid	Strand-ed Wire Double Braid	Solid Twin Wire	Stranded Twin Wires
0000	47–64	54–64	52–64	59–64	54–64x101–64	59–64x111–64
000	41–64	46–64	48–64	55–64	46–64x 87–64	55–64x103–64
00	38–64	43–64	43–64	48–64	43–64x 81–64	48–64x 91–64
0	36–64	40–64	40–64	45–64	40–64x 75–64	45–64x 85–64
1	33–64	37–64	37–64	42–64	37–64x 70–64	42–64x 79–64
2	29–64	33–64	32–64	37–64	33–64x 62–64	37–64x 69–64
3	27–64	31–64	30–64	34–64	31–64x 58–64	34–64x 64–64
4	25–64	29–64	27–64	31–64	29–64x 54–64	31–64x 58–64
5	24–64	28–64			28–64x 52–64	
6	22–64	26–64	24–64	28–64	26–64x 49–64	28–64x 52–64
8	18–64	22–64	20–64	23–64	22–64x 41–64	23–64x 42–64
10	16–64	20–64	18–64	21–64	20–64x 37–64	21–64x 38–64
12	15–64	19–64	16–64	20–64	19–64x 35–64	20–64x 36–64
14	14–64	18–64	15–64	19–64	18–64x 33–64	19–64x 34–64
16	10–64	13–64			13–64x 24–64	
18	9–64	12–64			12–64x 22–64	

Table giving the outside diameters of rubber covered wires for use on Voltages between 600 and 3500.

Size B. & S. Gauge	Solid Wire Single Braid	Solid Wire Double Braid	Strand-ed Wire Single Braid	Strand-ed Wire Double Braid	Solid Twin Wire	Stranded Twin Wire
0000	49–64	56–64	53–64	61–64	56–64x105–64	61–64x114–64
000	46–64	53–64	50–64	57–64	53–64x 99–64	57–64x107–64
00	41–64	46–64	47–64	53–64	46–64x 87–64	53–64x 99–64
0	38–64	43–64	42–64	46–64	43–64x 81–64	46–64x 88–64
1	35–64	40–64	39–64	43–64	40–64x 75–64	43–64x 82–64
2	33–64	38–64	36–64	40–64	38–64x 71•64	40–64x 76–64
3	31–64	36–64	34–64	38–64	36–64x 67–64	38–64x 72–64
4	29–64	33–64	31–64	35–64	33–64x 62–64	35–64x 66–64
5	28–64	32–64			32–64x 60–64	
6	27–64	31–64	28–64	32–64	31–64x 58–64	32–64x 60–64
8	24–64	28–64	26–64	30–64	28–64x 52–64	30–64x 56–64
10	22–64	26–64	24–64	28–64	26–64x 48–64	28–64x 52–64
12	21–64	25–64	22–64	26–64	25–64x 46–64	26–64x 48–64
14	20–64	24–64	21–64	25–64	24–64x 44–64	25–64x 46–64

NOTE.—These figures are taken from data furnished by one of the largest manufacturers of wire and are believed to be of at least as great dimensions as any standard wire on the market. Judgement must be used in applying these dimensions as the same size wire B. & S. gauge, of different makes often varies considerably in outside diameter.

Outside Diameters of Rubber Covered Cables.

Capacity in Cir. Mils.	Diameter over Braid
1,500,000	113–64
1,250,000	107–64
1,000,000	97–64
950,000	95–64
900,000	94–64
850,000	93–64
800,000	89–64
750,000	87–64
700,000	83–64
650,000	81–64
600,000	79–64
550,000	76–64
500,000	73–64
450,000	68–64
400,000	66–64
350,000	64–64
300,000	61–64
250,000	59–64

Outside Diameters of Weather-proof Wire.

Size of Wire	Outside Diameters.	
	Solid	Stranded
1,000,000	———	108–64
900,000	———	103–64
800,000	———	100–64
700,000	———	94–64
600,000	———	85–64
500,000	———	80–64
450,000	———	76–64
400,000	———	73–64
350,000	———	64–64
300,000	———	62–64
250,000	———	58–64
0000	50–64	55–64
000	47–64	51–64
00	39–64	43–64
0	36–64	39–64
1	32–64	35–64
2	30–64	33–64
3	27–64	30–64
4	25–64	28–64
5	22–64	24–64
6	20–64	22–64
8	17–64	18–64
10	16–64	
12	14–64	
14	12–64	
16	10–64	
18	8–64	

Dimensions of Unlined Conduit.

Nominal Internal Diam. Inches.	Actual Internal Diam. Inches.	Actual External Diam. Inches.	Thick-ness of Walls Nearest 64th
1/8	17–64	26–64	4–64
1/4	23–64	35–64	5–64
3/8	31–64	43–64	6–64
1/2	40–64	54–64	6–64
3/4	52–64	67–64	7–64
1	67–64	84–64	8–64
1¼	88–64	106–64	9–64
1½	103–64	122–64	9–64
2	132–64	152–64	10–64
2½	157–64	184–64	13–64
3	196–64	224–64	13–64

Dimensions of Lined Conduit

Nominal Internal Diameter Inches	Actual Internal Diameter Inches	Actual External Diameter Inches
1/2	32–64	54–64
3/4	45–64	67–64
1	58–64	84–64
1¼	80–64	106–64
1½	90–64	122–64
2	115–64	152–64
2½	144–64	184–64
3	176–64	224–64

DIMENSIONS OF PORCELAIN KNOBS.

Trade No.	Height	Diameters	Hole	Groove	Height of Wire
0	2¼	3	1¼	1	½
1	3	2⅛	7/16	¾	1¾
2	2	2	½	½	1
3	1¾	2	7/16	7/16	¾
3½	2	2	7/16	7/16	1
4	1 11/16	1½	⅜	⅜	⅞
4½	1⅞	1½	⅜	7/16	1
5	1¼	1	¼	5/16	¾
5½	1 9/16	1	¼	5/16	1
7	¾	⅞	¼	7/16	1⅛
9	1⅛	⅝	3/16	3/16	¾
10½	1¾	1⅝	⅜	⅜	1

DIMENSIONS OF GLASS KNOBS.

Trade Number	Height	Width	Size of Hole	Size of Groove
1	1½	1½	⅜	⅜
1½	1⅞	1½	⅜	⅜
2	1¾	2	⅜	⅜
3	2¼	2	⅜	9/16
7	2⅛	2	⅜	9/16
8	3¾	2¾	⅜	1″ cable

SIZES OF PORCELAIN TUBES.

Internal Diameter Inches	Shortest Length Obtainable	Greatest Length Obtainable	Outside Diameter
5/16	½	24	9/16
⅜	½	24	11/16
½	1	24	13/16
⅝	1	24	15/16
¾	1	24	1 3/16
1	1½	24	1 7/16
1¼	2½	24	1 11/16
1½	2½	24	2 1/16
1¾	2½	24	2 5/16
2	2½	24	2 11/16
2¼	2½	24	3 1/16
2½	2½	24	3 11/16

DIMENSIONS OF MOULDINGS.

Size of Groove	Size of Wire	Size of Groove	Size of Wire
7–32	14–12 B. & S.	3–4	0–0000 Stranded
5–16	10– 8 B. & S.	7–8	250.000 C. M.
13–32	6–5–4 B. & S	1	500.000 C. M.
9–16	3–2–1–0 B. & S.	1 1–4	750.000 C. M.

DIMENSIONS OF CLEATS.

ONE-WIRE CLEATS.

DUGGAN CLEAT.

No. 4	holds wires	16–8 B. & S.
No. 7	" "	6–2 "
No. 5	" "	2–00
No. 6	" "	000–300,000 C. M.
No. 8	" "	400,000–800,000 C. M.
No. 9	" "	900,000–1,200,000 C. M.

BRUNT CLEAT.

Stand. Number	Width	Length	Groove		
328	3/4	2	3/8	holds wires	16–5 B. & S
329	1	2 1/4	1/2	" "	8–3
321	13/16	2 3/4	11/16	" "	3–00
330	1 1/8	2 1/2	1/2	" "	4–1
332	1 1/4	2 7/8	15/16	" "	0–0000

TWO AND THREE-WIRE CLEATS.

BRUNT.

No. 334	2-wire	holds wires	16–8 B. & S
No. 337	3 wire	" "	16–8 B. & S

DUGGAN.

No. 3	2-wire	holds wires	16–8 B. & S.
No. 2	2-wire	" "	6–00 B. & S.
No. 1	3 wire	" "	16–8 B. & S.

PASS & SEYMOUR.

No. A-3	2-wire	holds wires	14–12 B. & S.
No. 3	2-wire	" "	14– 6 B. & S.
No. A–43	3-wire	" "	14–12 B. & S.
No. 43	3-wire	" "	14– 6 B. & S.

DIMENSIONS OF IRON SCREWS. APPROXIMATE.

Trade Number	Diameter in Fractions	Nearest B. & S. Gauge	Greatest Length Obtainable
0	7/128	15	3/8
1	9/128	14	1/2
2	5/64	12	7/8
3	3/32	11	1 1/4
4	7/64	9	1 1/2
5	4/32	8	2 1/4
6	17/128	7	3
7	19/128	7	3
8	5/32	6	4
9	11/64	5	4
10	12/64	5	4
11	13/64	4	4
12	27/128	4	6
13	29/128	3	6
14	15/64	3	6
15	1/4	2	6
16	17/64	2	6
17	9/32	1	6
18	19/64	1	6

DIMENSIONS OF COMMON NAILS. APPROXIMATE.

Trade Number	Diameter in Fractions	Nearest B. & S. Gauge	Length in Inches	No. per lb.
2d	9/128	13	1	875
3d	5/64	12	1 1/4	565
4d	7/64	10	1 1/2	315
5d	7/64	10	1 3/4	270
6d	7/64	9	2	180
7d	7/64	9	2 1/4	160
8d	17/128	8	2 1/2	105
9d	17/128	8	2 3/4	95
10d	19/128	7	3	70
12d	19/128	6	3 1/4	60
16d	5/32	6	3 1/2	50
20d	25/128	4	4	30

Fine Nails

2d	7/128	15	1	1350
3d	9/128	13	1 3/8	770
4d	5/64	12	1 1/2	470

RATING OF MOTORS.

Full Load Currents.

H. P.	110 VOLTS	220 VOLTS	500 VOLTS
1/8	1.9	.95	.42
1/4	2.7	1.35	.62
1/2	5.	2.50	1.15
3/4	7.5	3.75	1.70
1	9.2	4.60	2.10
2	17.5	8.75	4.
3	24.6	12.30	5.60
4	32.	16.	7.50
5	40.	20.	9.20
7½	57.	28.5	13.
10	76.	38.	17.5
15	110.	55.	25.
20	144.	72.	34.
25	176.	88.	40.
30	210.	105.	49.
35	250.	125.	57.
40	280.	140.	65.
45	320.	160.	75.
50	350.	175.	80.
60	430.	215.	100.
75	520.	260.	120.
100	700.	350.	160.
125	880.	440.	210.
150	1056.	530.	245.
175	1230.	615.	280.
200	1400.	700.	325.

RATING OF INCANDESCENT LAMPS.

110 VOLTS			220 VOLTS		
C. P.	Watts	Amperes	C. P.	Watts	Amperes
4	18	.16	8	36	.16
6	24	.22	10	45	.20
8	30	.27	16	64	.29
10	35	.32	20	76	.35
12	40	.36	24	90	.41
16	56	.51	32	122	.55
20	70	.64	50	190	.86
24	84	.76			
32	112	1.00			
50	175	1.60			

The Cooper-Hewitt Mercury Vapor lamp requires a current of about 3.5 amperes.

The Nernst lamp consumes 88 watts per glower; for a 6 glower, 110 volt lamp, about 4.8 amperes.

Series miniature lamps, operated 8 in series, on 110 volts, require a current of about .33 amperes for 1 candle power lamps, and 1 ampere for 3 candle power lamps.

Tables showing the currents which will fuse wires of different substances.

B. & S. Gauge	Diam.	Copper	Aluminum	German Silver	Iron
10	102.	333.	246.5	170.	102.3
12	81.	236.	174.4	120.5	72.6
14	64.	165.7	122.8	84.6	50.9
16	51.	117.7	87.1	60.1	36.1
18	40.	81.9	60.7	41.8	25.2
20	32.	58.5	43.4	29.9	18.
22	25.3	41.1	30.5	21.0	12.4
24	20.	28.9	21.5	14.8	8.9
26	16.	20.7	15.3	10.6	6.4
28	12.6	14.5	10.7	7.4	4.5
30	10.	10.2	7.6	5.2	3.1
32	8.	7.3	5.4	3.7	2.3
34	6.3	5.1	3.8	2.6	1.6
36	5.	3.6	2.7	1.8	1.1

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