RULES

FOR INSTALLING

ELECTRIC LIGHT AND POWER APPARATUS

CONSISTING OF THE

"NATIONAL ELECTRICAL CODE"

WITH

EXPLANATORY NOTES

1904

NINTH EDITION

INSPECTION DEPARTMENT

Associated Factory

Mutual Fire Insurance Companies

31 Milk Street, Boston, Mass.

APPROVED FITTINGS

For satisfactory work, only approved fittings should be used. A pamphlet entitled "Approved Electrical Fittings," designed to aid wiremen by showing them in advance just what will be approved, is issued by this department.

Fittings not listed should not be used without special approval, which will be freely given on the application of members if the device is found to be reliable.

"Approved Electrical Fittings" is subject to semi-annual revision in April and October.

PREFACE TO NINTH EDITION.

As in previous editions, the National Electrical Code is given in full, with explanatory notes to make the reason for each rule clearer and to point out the special danger against which it guards. In some cases these notes so modify the rules or extend their application as to have practically the effect of additional requirements applying to factory work. A number of cuts illustrating excellent methods of construction have also been included to still further emphasize and make clear important points frequently overlooked. The testimony of many wiremen and mill managers and our own experience have shown that the suggestions contained in these additional notes and cuts have been carried out to advantage in many cases, resulting in a more convenient and safer electric plant. In the Appendix is some additional information which could not well be included in the body of the Rules.

Power Stations, Transformer, Lightning Arrester and Switch Houses have in a number of instances been constructed largely of wood, which is objectionable; even where well built originally, stations have been rendered unsafe by the introduction of combustible materials for apparatus, wire frames, platforms, etc. In this edition, therefore, a special chapter, page 3, has been added, in which is outlined the important points essential for safe buildings and equipments of this kind. This matter is considered of great importance.

To enable those not especially familiar with electrical matters or too busy to give more than a few minutes to the subject, to quickly gain an idea of the Rules, a brief abstract of the requirements applying to Factory Mutual mills is also given, page 13, and special attention is called to this section.

It is impracticable to prepare a set of rules which will wisely cover every case, and the applications of electricity are still in a state of frequent change. If, therefore, in any instance it may appear that these rules do not cover the peculiar existing conditions in the best way, this department will be pleased to give special consideration to the case.

The notes in connection with the rules and cuts have been prepared in consultation with Professor William L. Puffer, of the Electrical Engineering Department of the Massachusetts Institute of Technology.

9th Edition, 6000,
July, 1904.

The "National Electrical Code," as it is here presented (see page 23), is the result of the united efforts of the various insurance, electrical, architectural and allied interests which have, through the National Conference on Standard Electrical Rules, composed of delegates from various national associations, unanimously voted to recommend it to their respective associations for approval or adoption. The following is a list of the associations represented in the Conference, all of which have approved of the Code: —

American Institute of Architects.
American Institute of Electrical Engineers.
American Society of Mechanical Engineers.
American Street Railway Association.
Associated Factory Mutual Fire Insurance Companies.
National Association of Fire Engineers.
National Board of Fire Underwriters.
National Electric Light Association.
National Electrical Contractors' Association.
Underwriters' National Electric Association.

POWER HOUSES, TRANSFORMER STATIONS, AND GENERAL SUGGESTIONS FOR LARGE MILL POWER AND LIGHTING PLANTS.

These suggestions are intended especially for electric plants of fairly large capacity or high voltage, and for the rooms or buildings containing such equipments. Large values are frequently concentrated in such power and transformer houses, so that there is a chance of large loss from fire or water. There is often delay in repairing or replacing damaged electric machinery, which may easily result in a greater loss than the fire itself, due to the stoppage of motors and lights which are directly dependent on the power station. It is therefore of the greatest importance that these centres of power be made as fireproof as possible.

It is not intended in these suggestions to include the ordinary engine room, in which a few comparatively small, low-voltage generators are installed. Such rooms should ordinarily have the usual sprinkler protection of the mill. In brief, the construction must be fireproof, or else sprinklers must be provided.

Locations. — The location of the power house will usually be fixed by convenience to water or coal supply, as in the case of the water power station shown in Fig. 1. Where step-up transformers of large capacity or for very high voltages are used, a separate transformer building, detached from the main power house, is desirable, in order to keep the high voltages and possibilities of lightning troubles absolutely out of the power house. For smaller equipments, a transformer room in the power house, but with a fire wall between it and the main generator room, may be provided.

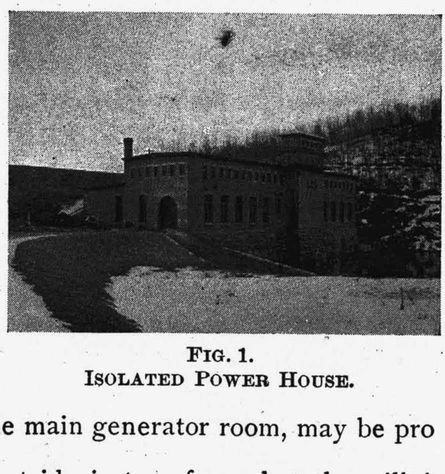


FIG. 1.
ISOLATED POWER HOUSE.

Where current from outside is transformed at the mill, it is desirable to place the transformer house outside the main building groups so that the high-voltage wires will be absolutely out of the way in case of fire. Such a transformer house would contain the necessary lightning arresters and switches, so that all current could be cut off from the buildings.

Fig. 2 well illustrates just such a building. This transformer house is located on the bank of a river opposite the mill supplied by the transformers, the 550 volt secondary wires which are carried across the river being plainly seen in the cut where they leave the building. The 2000 volt primary wires are brought along the river bank and enter the transformer house as shown at the left of the cut. As fire in the wooden shed back of the building could not be fought from the river side, the high-tension wires would not be in the way of the firemen even in case of fire here, so that the location of the transformer house is excellent. The arrangement of lightning arresters, switchboard, transformers, etc., is well shown in Fig. 6, page 8.

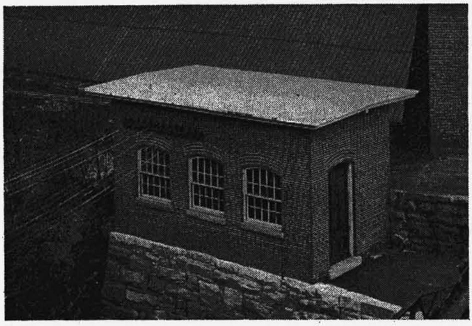


FIG. 2.
SEPARATE TRANSFORMER HOUSE.

Where there are no transformers, a small switch and lightning arrester house near the point where the wires enter the yard, and away from main buildings, is desirable for similar reasons. It is a good plan to carry the wires underground from such a transformer or switch house to the buildings, but where this cannot be done, the overhead wires should be most carefully arranged, so as not to be in the way in case of fire.

Fig. 3 shows a terminal house for a 13,000 volt line. This house contains only the lightning arresters and high-tension switches, and is located well away from other buildings. From this house the high-voltage wires are carried underground to the transformer house, so that the chance of accidental contact with these dangerous circuits, or their interference with firemen in the vicinity of the main buildings, is reduced to a minimum. This terminal house is entirely fireproof, and the only openings are the window shown in the cut and a door in the opposite wall. Where a connection from a high-voltage transmission line must be brought into a mill yard, the above arrangement is excellent from a fire standpoint.

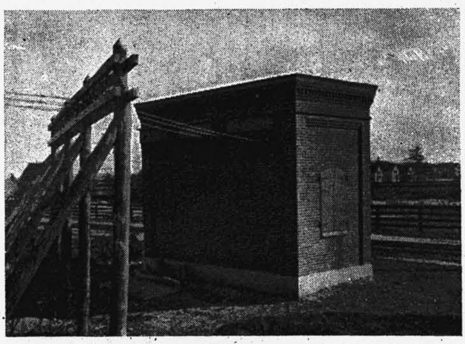


FIG. 3.
FIREPROOF LIGHTNING ARRESTER AND SWITCH HOUSE.

Construction. — Power houses and transformer and switch stations should be thoroughly fireproof. The walls should be of brick or equivalent, and should be bare on the inside, without combustible finish of any kind. Pressed or enameled brick may be used where artistic finish is desired. The floors should be fireproof, and with no wood or combustible top flooring except such small sections as may be desired around high-voltage apparatus, and any such sections should have no hollow spaces under them in which dirt might collect or a fire gain headway. For large stations the roofs should also be entirely incombustible. For stations of moderate size, 1000 H. P. or less, and where the roofs are 20 or 25 feet above the electrical machinery and free from wiring, a solid plank and timber roof may be built if an incombustible roof is objectionable on account of expense or for other reasons. The exposed wooden surfaces of both plank and timber in such a roof should then be fireproofed. Where there are no wires near the roof, this fireproofing may be done by covering the surfaces with expanded metal lathing and hard plaster. Where wires, especially of high-tension circuits, run over such ceilings, metal lathing is not desirable, and a covering of two layers of ¼ inch Sackett plaster board or equivalent laid to break joints, and the whole covered with hard plaster, may be used.

In general, such fireproofed roofs may be used also on all except large transformer stations, and on switch and lightning arrester houses unless these contain apparatus of considerable value, in which case an entirely fireproof building would generally be advisable.

The above points are well illustrated in Fig. 4, which shows an interior view of the power house shown in Fig. 1, page 3. Attention is called to the very high roof which in this case is built of plank and timber fireproofed with expanded metal and plaster as suggested. See also Fig. 6, page 8, where this same style of roof is shown for a transformer house.

The objection to metal lathing in the vicinity of high-tension circuits is that in case of a short-circuit or other disturbance on these wires, the arc might follow to the metal work, and in attempting to get to the ground, would be liable to start other arcs at different points, which might destroy the ceiling or ignite the woodwork back of the fireproofing. In such cases, therefore, the plaster board is preferable.

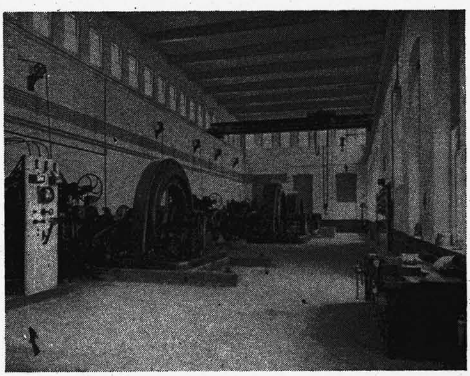


FIG. 4.

INTERIOR OF POWER HOUSE SHOWN IN FIG. 1, PAGE 3.

Wire Towers. — Where the distributing circuits are run overhead, a wire tower is frequently the most convenient and best method of connecting with the outdoor lines. Such a tower should be entirely fireproof, and completely cut off from the rest of the station. There should be as few openings as convenience will permit between the tower and the station, and each opening should have a standard self-closing fire door.

In order to keep as much of the wiring out of the main room as possible, the switchboard can often be advantageously built into the wall of the tower, but leaving no opening between the tower and the main room, except as above. This arrangement brings the back connections on the board into the tower, where they can be readily connected to the risers, and it puts the considerable mass of wires, which necessarily concentrate toward the back of a large switchboard, where short-circuits or fire can do no damage to the main and expensive part of the apparatus, and furnishes a convenient place in which to make repairs and changes in wiring, switchboard connections, etc.

In Fig. 4, page 5, the main switchboard may be seen on the right-hand wall. This board is located at the bottom of the wire tower shown in Fig. 1, page 3. Fig. 5 gives a nearer view of the board, which, as shown, is set flush with the wall as above suggested. The opening at the right of the board, however, should be protected by an automatically closing fire door in order to thoroughly cut off the tower from the main room. Back of the board are located the switchboard, transformers, oil switches, etc. This makes a very convenient and safe arrangement for switchboard and wire tower.

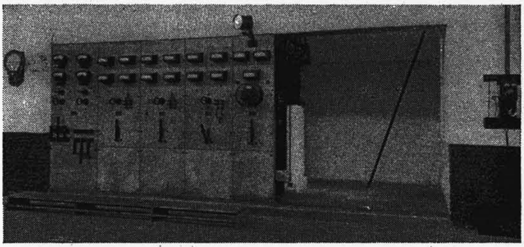


FIG. 5.
SWITCHBOARD BUILT INTO WALL AT BOTTOM OF WIRE TOWER.

Underground Conduits and Wire Tunnels.—Where the distributing mains are run underground, a conduit system is believed the safest and best arrangement. A tunnel for the wires may, however, be built if preferred, but should not open directly into the power station or transformer house nor into any important building; connection into such buildings should be made by wires passing through bushings built in the walls. If necessary to enter the tunnel from a station or other building, a small doorway may be provided in the separating wall and protected with a standard automatically closing fire door. Other access to the tunnel may be provided by outside openings suitably protected from the weather.

Long wire tunnels, especially those of any considerable size, should be subdivided by brick walls about every 250 feet, the wires passing through the walls in bushings cemented in and of such sizes as to fit the wires as closely as practicable. The wires should then be built up with tape, if necessary, to entirely fill the bushings. Small doorways may be made through such walls, each opening being equipped with an automatically closing fire door.

The subdividing walls are desirable in order to limit any trouble to a small section. Otherwise a bad short-circuit or a fire from any cause might extend the entire length, as the ordinary insulations, even where a slow-burning outer braid is used, will burn when thoroughly heated, and in such wire tunnels there are likely to be so many wires running close together that in the aggregate there would be considerable combustible material. The ordinary methods of fire-fighting would not be applicable in such cases, as access to the seat of the fire would be prevented by smoke and heat. Each section should be ventilated out of doors so as to keep the tunnel cool, and also to facilitate the escape of smoke and gases in case of accident. In tunnels, wire having a slow-burning outer insulation should always be used.

It is therefore evident from the fire standpoint that the conduit system is preferable, as a short-circuit or other disturbance would rarely extend beyond the point of starting, and would be much less liable to involve all of the circuits. Convenience of operation and extension, such as the withdrawal and insertion of wires and the adding of new circuits, can be readily taken care of by means of manholes at different points and the laying of a few extra ducts when the system is put in.

In conduits the wires are not subject to great changes in temperature, as often occur in tunnels, where steam pipes, water mains, etc., are often placed along with the wires.

Partitions, Offices, Supply Rooms, and General Interior Finish. — Many otherwise excellent stations and transformer houses have been rendered absolutely dangerous by the introduction of wooden sheathing, partitions, shelvings, etc. Starting with the fundamental idea that the station shall be fireproof, it is essential that, in addition to incombustible walls, floors, and roofs, there should be almost nothing inside the building which can burn. Where the electrician's office is more than a simple desk and chair occupying one corner of the main room, for example, it should be cut off by fireproof partitions and protected by automatic sprinklers. The supply room should be cut off and sprinkled. Basements, although built all fireproof, almost invariably at times have more or less combustible material stored in them in the shape of supplies, packing cases, etc., so that they should generally be sprinkled. It is in fact rather better, where possible, to build stations without basements, putting the main floor directly on the ground and providing storage and office rooms in an adjacent section, cut off by a fire wall.

Boiler rooms, where adjoining power or transformer houses, should be separated by fire walls with but few openings through them, and standard automatically closing fire doors should be provided at each opening.

Arrangement of Apparatus. — The apparatus, such as generators, switchboards, transformers, etc., should not be crowded, but should have liberal space around each piece in order to give free access to all parts for changes, repairs, etc., as well as for convenient care and manipulation.

These points have been well carried out in the generator and transformer rooms shown in Figs. 4 and 6, pages 5 and 8.

Wiring. — All open wiring in stations, transformer and switch houses, wire towers and tunnels, should have incombustible insulations or at least slow-burning outer braids. For low-voltage equipments (550 volts and less) slow-burning weatherproof insulation (see Rule 42, page 88) is satisfactory. For high voltages rubber insulation is necessary, but this should have a heavy, slow-burning outer cover which will prevent flames running over the wire or the rapid combustion of the rubber.

Rubber wires with such slow-burning outer braids have been in use for some time, although to a limited extent. They can, however, be readily procured from most of the wire manufacturers. Wire having insulation composed largely of asbestos has recently been placed on the market. This is mainly incombustible, and therefore especially adapted for power station work in dry places. It would not do where there was danger from dampness.

Transformer Building. — Transformers, as stated, should not be located in the main power house except for comparatively small plants. The construction and fitting-up of a transformer house should follow closely the preceding suggestions for power houses. The main point is to have practically nothing to burn, and to have all parts of the apparatus readily accessible. The transformers should be set on brick, concrete, or stone foundations, and, where of the air blast type, all air passages should be incombustible. Wooden wire racks and frames should be avoided, and, where some wood is desirable for insulation, it should be in solid pieces, generally hard wood, and with not enough bunched together in any one place to support combustion.

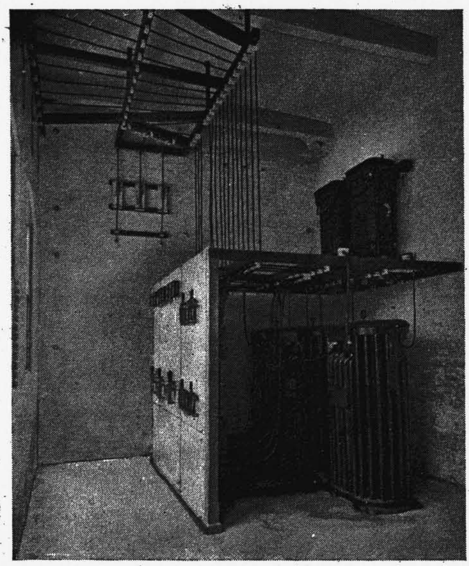


FIG. 6.
INTERIOR OF TRANSFORMER HOUSE SHOWN IN FIG. 2, PAGE 4.

The transformer house should be well ventilated to prevent the accumulation of explosive vapors which may be given off from the oil when hot, and to facilitate keeping the room cool, thus preventing overheating of the transformers. Good ventilation also assists in removing smoke in case of fire in the transformers, and allows men to enter and extinguish the fire, which would not be possible were there not free outlet for the smoke. Floors should also be kept clean and free from oil.

Fig. 6 gives an interior view of the transformer house of Fig. 2, page 4, and shows a very good arrangement of the apparatus. The primary wires are brought directly to fuses and oil switches on the switchboard, and then run to the several transformers. The remainder of the board is used for the secondary fuses and switches, as each secondary circuit is controlled at this point. As a rule, this would not be considered necessary, but was done in this case for convenience and to permit of cutting off all current from circuits not in use. The room shown is 27 ft. by 13 ft. by 16 ft. high. The ceiling is fireproofed with wall board and hard plaster. It would have been better to have made the wire racks largely of angle iron instead of wood, in order to have as little combustible material in the room as possible. The cut also shows the desirability of using slow-burning insulation on the wires, for where they are grouped as in this case the ordinary weatherproof or rubber insulation would allow fire at the transformer or switchboard to spread rapidly throughout the room.

Lightning Arrester Room. — Lightning arresters and choke coils should generally be in fireproof rooms. At the station these may be at the top of the wire tower; at the transformer building they may be in a small section partitioned off from the main transformer room. Woodwork should be avoided in the construction and mounting of choke coils, and in general the same entire absence of combustible materials should be required as in the power station itself.

Fire Protection. — Although the intention is to have practically nothing to burn in the buildings under discussion, experience shows that even with the best of care combustible material frequently gets into such places, as, for example, packing boxes and blockings, stagings, etc., used during repairs, temporary woodwork used in connection with experiments or for some other special purpose not originally contemplated, but often resulting in sufficient fuel to be dangerous. A moderate amount of protective equipment is therefore necessary for reasonable safety.

With the thoroughly fireproof construction advised, automatic sprinklers would generally not be necessary in the main generator or transformer room or in switch houses. There should, however, be a good supply of fire pails kept full at all times. There should also be several lengths of approved brand 1½ inch linen hose, with smooth nozzles. Enough lines should be provided so that a stream of water can quickly be brought to bear at any point, and two streams at any place where there may be special danger. Sprinklers should be provided in basements, supply rooms, offices, locker rooms, etc., where there is sure to be more or less burnable material. Fireproof *construction* does not prevent the *contents* of a room from burning with dangerous results.

In older stations which may have plank roofs and floors, sprinklers should usually be provided throughout, as it is better in most cases to take the risk of some added water damage than the certainty that under many conditions fire would destroy the station. Where the danger of fire is not too great, sprinkler heads in such cases directly over generators and switchboards may be supplied through a separate pipe, and the water kept shut off by a valve accessibly located outside of the room protected.

For stations of considerable value, or of great importance for the maintenance of electric current supply, one or more frostproof hydrants outside, from which streams may be obtained in case of some unexpected need, should be provided. It is well to cover these hydrants with standard hose houses fully equipped with hose, play-pipes, etc. The capacity of such outside equipment needed will of course depend on the value and importance of the station, its construction, the probability of combustible materials ever being introduced, and the exposure in case of fire in any surrounding buildings.

There may seem little need for this heavier apparatus where the stations are all incombustible; our whole experience, however, shows that conditions often change, that dangerous features creep in now and then, and that temporary needs often result in objectionable expedients; so that, taking it altogether, to make such a station thoroughly safe and as good a risk as the average fully equipped Mutual mill, it is necessary to have some outside equipment, though of lesser extent and capacity, on account of the fireproof construction, than would be required for a factory building of the same value.

Small hose and sprinklers must be supplied from some reliable *gravity* source, as a good public water system, a private reservoir on a near-by hill, or a liberal tank on a high trestle. The same source of supply is desirable for hydrants, although a pump could of course be used where it could be located so that it would be safe and have power even though there were a bad fire in the station. A good public fire department quickly available and with some reliable water supply would lessen and perhaps remove the need of outside equipment.

The power house shown in Fig. 1, page 3, is a good example of an isolated station needing just about such a fire protective equipment as above outlined, as the plant is not within easy reach of a public department or other outside aid. A reservoir of about 60,000 gallons capacity was therefore built on the hill shown in the cut, giving about 50 lbs. pressure at the power house. An 8 inch main from this reservoir supplies two 2-way yard hydrants, a few sprinklers around heating apparatus, etc., and several lines of inside hose. A pump good for one fire stream is also connected and ordinarily used for filling the reservoir. It, however, would be of considerable service in case of brush fires in the vicinity of the station or in the event of fire in any neighboring dwellings which might be built for the use of the station men, etc. Moreover, by locating this pump in a safe place, as above suggested, it would be available at time of fire in the power house itself.

Important transformer stations should have substantially the same sort of protection. Small switch and lightning arrester houses having comparatively little value would not ordinarily need special protection other than a few fire pails, but should be kept absolutely free from combustibles, as a slight fire might be troublesome from interruption of the service, though the actual money loss might be slight.

While the above covers the general requirements, each case usually needs some special study to get at the best results, so that it is desirable to take up this whole question of fire protection, as well as the general arrangement of the electric equipment, with the Underwriters before contracts are finally made.

For extinguishing fires in transformers, especially where oil cooled, so-called dry powder extinguishers thrown into the cases during the early stages have been found very effective.

The efficiency of such powders for this work is undoubtedly due to the fact that the casings confine the gases from the powder so that they displace the air, and the fire, which has not gained great heat, goes out from lack of oxygen. With oil transformers water is of little use except to protect the surroundings, and the fire in the transformer must be smothered either by such gases or by stopping up all vents.

Such fires cannot be handled at a distance, but must be fought at close range, which also emphasizes the necessity of so building and ventilating the houses that they can be entered during a fire. With an air blast transformer on fire, the dampers should be immediately closed and the fans stopped; then the powder extinguishers or other methods can be applied.

A dry powder mixture of bicarbonate of soda and oxide of iron in the proportion of 9 pounds of soda to 1 pound of iron makes a good fire extinguisher. The soda breaks up with heat, forming carbonic acid gas. The purpose of the iron oxide is simply to prevent caking due to dampness. The oxide should therefore be thoroughly mixed with the soda. It is well to keep such powder in metal cans with a fairly tightly fitting cover, thus keeping it practically dry.

It is strongly urged that every mill having an electric light or power plant should set aside a small room for the systematic storage of approved fittings, and should keep on hand a sufficient supply to insure that all repairs or extensions may be properly done. This will frequently prevent the use of makeshifts when fittings give out, and will be an incentive to the man

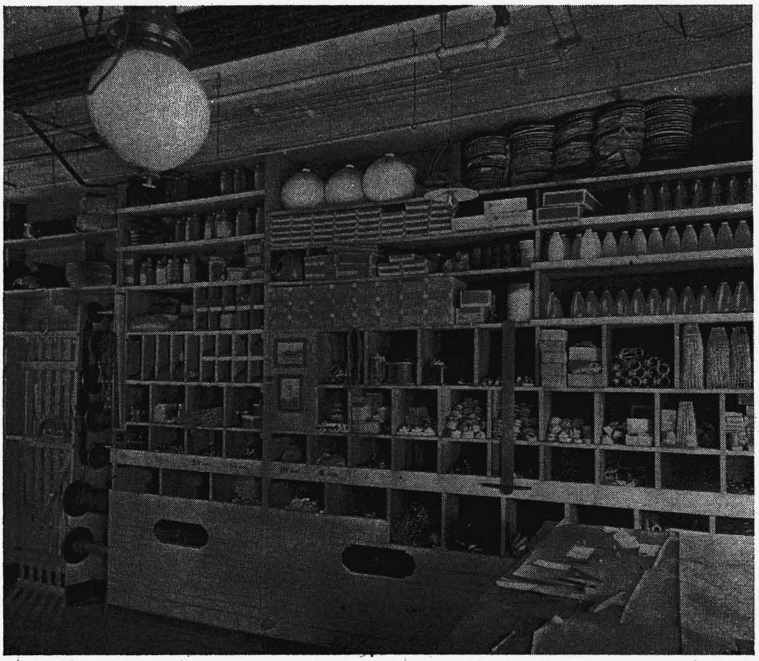


FIG. 7.
STOCK ROOM FOR ELECTRICAL FITTINGS.

in charge of the electric plant to keep everything about it in first-class condition. This room should be kept locked, and none but authorized persons should have access to it.

This is undoubtedly a large part of the secret of keeping a plant in good shape and up to date without special periods of more or less expensive overhauling.

Fig. 7 shows a section of a well arranged and well kept mill stock room for electrical supplies. This room also contains the electrician's drawing table, electrical measuring instruments, etc.

THE RULES IN BRIEF.

The following abstract of the Rules gives in concise form the general requirements for average Factory Mutual mills, and calls special attention to a number of important points frequently overlooked when laying out a plant.

Contracts.

It is advised that all contracts for electrical work contain the following clauses: —

All work shall conform strictly to the requirements given in "Rules for Installing Electric Light and Power Apparatus," issued by the Inspection Department of the Associated Factory Mutual Fire Insurance Companies.

No fittings shall be used which are not listed in the latest edition of "Approved Electrical Fittings," issued by the Inspection Department of the Associated Factory Mutual Fire Insurance Companies.

Generators.

Generators should be located in clean, dry places, away from combustible materials; and a light location rather than a dark one is always preferable. It is not desirable to place them in the work-rooms of a plant where combustible material abounds, as in the ordinary textile mill, though they may sometimes be so located if properly cut off from the main room by a dust-tight plank partition. A location suitable for a first-class steam engine is none too good for a generator.

A solid foundation is necessary for smooth running. The generator frame should, where possible, rest on timber supports, and should be fastened to them by lag screws or bolts which do not pass through in such a way as to electrically connect the frame with the ground. Two parallel timbers, as shown in Fig. 14, page 34, are preferable to a four-sided framework, which encloses a place under the machine that is difficult to keep clean.

Motors.

The use of voltages above 550 in rooms where manufacturing processes are being carried on is rarely advisable or necessary, and will only be approved when every possible safeguard has been provided. Plans for such installations should be submitted to the Inspection Department before work on them is begun.

Direct-current motors and alternating-current motors with brushes should be so located or enclosed, especially in dusty or linty places, that inflammable material or flyings cannot accumulate around them and become ignited by serious sparking at the brushes. Similar protection should also be provided in wet places, as most electrical machinery is injured by continued exposure to moisture.

Alternating-current induction motors of the type without brushes can be safely located in almost any part of a textile plant without being enclosed, being generally no more dangerous than any other piece of machinery running at the same speed.

For light work, direct-current motors which have all of the working parts enclosed in an iron case are on the market, and these "enclosed" motors may be treated in the same way as induction motors without brushes.

Where an enclosure around the whole motor is provided, it should include the starting rheostat or auto-starter, as well as the main switch and fuses or circuit-breaker, and should, if possible, be of such a size as will permit the attendant to enter it and easily get at any part of the apparatus. It should preferably be made largely of glass, so as to keep the motor in full view of the attendants, thus promoting cleanliness and making it possible to quickly discover any derangement. (See Figs. 17 and 18, pages 36 and 37.) It should also be thoroughly ventilated, in order to prevent undue heating of the electrical machinery.

Where a motor is permitted to be used in a dusty or linty place without being enclosed, or if the enclosure provided for it is too small to include anything else, the rheostat or auto-starter and the main switch and fuses or circuit-breaker should be placed in a dust-tight wooden cabinet. (See Fig. 16, page 35.) Similarly, in wet places, these accessories should be protected from moisture in a cabinet which is thoroughly water-tight.

Switchboards.

Switchboards should be made of slate or marble, supported on metal frames, and should be located well away from combustible materials. They should always be open at the sides, and a space of at least 12 inches should be left between the floor and the board, and 3 feet, if possible, between the ceiling and the board, in order to lessen the danger of communicating fire to the floor or ceiling, and to prevent the formation of a partially concealed space, very liable to be used for the storage of rubbish, oily waste, etc. (See Figs. 9 and 10, pages 27 and 28.)

The instruments should be neatly arranged and the wiring on the back should be laid out in a careful and workmanlike manner.

It is recommended that all live parts, such as bus-bars and other conductors, be protected against accidental contact as far as practicable by suitable insulation, which shall be "flame-proof" or "slow-burning" and designed to withstand a reasonable amount of abrasion. The chances of accidental short circuit and arcing at these points may thereby be greatly reduced. Insulated cable for bus-bars and connections is excellent for this purpose. However, the conductors could be wrapped or taped if this should be found more convenient, but this method should never be used unless it can be done *well.* Special precautions might also be necessary with either method if applied to high-voltage switchboards. (See Rule 3 *a*, page 27.)

In addition to the usual measuring instruments and other apparatus, the switchboard should contain reliable devices for testing for grounds. The usual forms of ground detectors are described in the Appendix, page 123.

Dynamo Room Wiring.

Since there is generally a considerable number of wires brought close together in this room, particularly in the vicinity of the switchboard, the use of a "slow-burning" insulation is of great importance, and attention is therefore called to the paragraph on "Inside Wiring," page 16. As automatic sprinkler protection is not always advisable in dynamo rooms, the necessity for reducing as far as possible the chances of a fire at this point is at once evident. The desirability of fireproof construction throughout the dynamo room is especially emphasized in the chapter on power houses, etc., page 3.

Special care should be exercised in rigidly supporting and thoroughly insulating the wires from generator to switchboard, as the main fuses are usually on the switchboard and a short-circuit between these wires would, therefore, be likely to burn out the armature.

Outside Wires.

All outside lines should be carefully laid out through mill yards, so as not to interfere with fire streams or ladders, a definite plan being determined upon before work is commenced. Many wiremen are very careless about this matter, and if not cautioned will run the wires in the easiest way, regardless of looks or safety.

Wherever a high-voltage circuit enters the mill yard from a distant station, outside emergency switches should be so placed that in case of fire or other accident the current can be quickly and safely cut entirely out of the yard. (See Rule 22 *a*, page 65.) Telephone or call-bell service from the mill to the power station is not usually sufficiently reliable to make these switches unnecessary. Lightning arresters should be provided on all wires which are liable to receive lightning discharges.

Fire Lights.

It is a good plan, where possible, to arrange in yards and buildings, on circuits entirely out of the way of ladders or fire streams, a few lights which may be thrown on at the time of a fire when the main lights are off, enabling firemen to move about quickly and safely.

Such lights can generally be best arranged on entirely separate circuits, and will often be useful for repair work and for lighting the help into and out of the mill, when the main lights are off. These circuits may take current from a small, separate generator, driven by an independent engine or water-wheel; or from outside lines; or possibly from a storage battery, so isolated from the main buildings as not to be affected by a fire in them.

Transformers.

Where transformers are to be connected to high-voltage circuits, the Inspection Department should always be consulted before work is begun or the apparatus is purchased, as it is necessary in many cases, for best protection to life and property, that the secondary system be permanently grounded, and this cannot be done unless provision is made for it when the transformers are built.

Transformers should always be located ouside of buildings, unless special permission is given to put them inside. In general, it is dangerous to locate transformers with oil-filled cases inside, as it is entirely possible for a break-down of insulation to ignite the oil, which may result in a very stubborn fire. For the same reason, the placing of these transformers on roofs is also objectionable.

Even transformers which are not oil cooled may contain a considerable amount of combustible material which, if ignited, would make a hot fire, especially if the cases are ventilated as is customary with these types of transformers. Moreover a burn-out in the windings may cause dense smoke, which might easily be mistaken for a fire and cause fire streams to be thrown into the building, with a resultant water damage. They can, therefore, be permitted inside of buildings only after the circumstances have been carefully considered and the necessary safeguards provided.

Inside Wiring.

Rubber-covered wire must be used in all damp places, in all conduit, moulding or concealed work, and throughout all systems on which the voltage exceeds 550.

For "open" work in dry places where the voltage is not over 550, rubber-covered wire may be used if desired, but slow-burning weatherproof wire fulfills every requirement for such work, in fact is preferable, and is less expensive. This wire has special merit for use in linty and dusty places, for lint does not readily adhere to the hard, smooth, outer surface, as is the case with wires having a weatherproof braid on the outside which in warm rooms becomes sticky. Moreover what little lint may collect upon it can be easily brushed off, so that when "sweeping down" there is much less liability of breaking the insulators or badly deranging the wires.

Where of necessity a considerable number of "open" wires are brought close together as, for example, about the ordinary distributing switchboard, the wires should have either the slow-burning weatherproof insulation as just described, or a rubber insulation protected by a heavy "slow-burning" outer braid.

The weatherproof and rubber insulations in common use contain a large amount of inflammable material, which ignites easily and produces a fierce fire and dense smoke. It is therefore desirable to reduce, as far as possible, the amount of this inflammable material and to surround it with a tight, "slow-burning" cover to prevent rapid combustion. To still fur-

ther reduce the amount of combustible material, the porcelain insulators by which the wires are held in place may be supported on an iron frame. (See Fig. 8, page 26.)

Before beginning work the circuits should be carefully mapped out and the work so planned as to secure the very simplest arrangement. The wiring should then be put up in a neat manner, and should present a thoroughly workmanlike appearance. (See Fig. 33, page 57.)

In many cases far too little attention is given to this matter while the work is in progress, the result being a general disappointment to all interested in the plant, especially to those who understand what a really first-class job of wiring looks like. This disappointment is probably felt by nobody more than by the owner, when he realizes that with reasonable care and common sense a better and undoubtedly safer equipment could have been installed at practically the same expense.

In mill work, "open" wiring securely supported on porcelain insulators is generally best. Mains of No. 8 B. & S. gage wire and larger are usually most conveniently carried through space from timber to timber and supported at each timber only. Smaller wires thus supported would be liable to be broken, and should therefore be wrapped around the beams or carried through them in holes bushed with porcelain, or they may be fastened to strong running-boards, well put up. The idea is to have the wires so rigidly supported on proper insulators that, even if they were bare, the insulation of the system would be perfect. All joints should be securely made and then carefully soldered and taped.

Wires should be carefully protected where liable to be deranged or injured, as in passing from story to story up side walls or columns, or near belts, or over shelves and similar places where anything is likely to be piled against them. Excellent protection can be secured by carrying them through iron pipe, first reinforcing the insulation of each wire by enclosing it in flexible insulating tubing. On alternating-current systems, the two or more wires of the same circuit should be run in the same pipe to avoid induction effects. (See Figs. 35 to 38, pages 69 to 71.) Even on direct-current systems this arrangement is best, as then the expense and inconvenience of rewiring is avoided when it is desired to change such systems to alternating current, which frequently happens. Protection may also be obtained by strong wooden boxing, with a slanting top to keep out dirt, the holes through which the wires enter the top being bushed with short porcelain tubes. (See Fig. 35, page 69.)

The use of incandescent lamps in series on constant-potential systems is not approved. (See Rule 21 *d* note, page 64.)

Switches.

Knife switches should be enclosed in cabinets in all dusty or linty places or when so located that persons would be liable to come in contact with the bare terminals. Up to 250 volts and 30 amperes, approved indicating snap-switches are considered preferable for use on lighting circuits.

Cut-Outs.

Link fuses are not advised for general use about a factory, and will not be approved, unless mounted on slate or marble bases made to conform to the specifications given in Rule 52, page 101, and enclosed in dust-tight, fireproofed cabinets. (See Figs. 43 and 44, page 109.) The ordinary porcelain link-fuse cut-outs are not permissible. Approved plug and cartridge fuses may be used almost anywhere in the ordinary manufacturing plant without the enclosing cabinet, such cabinets being necessary only in specially hazardous places, or where persons would be liable to come in contact with the bare terminals. These fuses of the enclosed type are strongly recommended for general use.

The enclosed fuse has recently been standardized by a special committee of the underwriters in consultation with the fuse manufacturers. (See specifications, page 105.) This was found necessary in order to secure an interchangeable fuse for any given capacity regardless of the make. This feature has heretofore been sadly lacking, and the result has been great inconvenience or the use of dangerous substitutes, such as fuse wire, wire nails, etc. The great advantages of an interchangeable fuse are evident, and it is urged that the National Electrical Code Standard fuse be used generally.

Rosettes.

Either fused or fuseless rosettes may be used as desired. With fuseless rosettes the number of 16 c. p. lamps per circuit should not exceed 12, and for convenience the branch cut-outs should be located over alleys or in other readily accessible places. With fused rosettes, 30 or 40 lamps could be placed on one circuit if desired, but it is better practice to have a smaller number, so that the blowing of the fuse at a branch cut-out will not extinguish so many lights.

Flexible Cord.

With the exception of wet rooms, storehouses, and specially hazardous rooms of textile mills and the like, approved flexible cord may be used for all pendants which hang freely in the air. If the lamp is to be moved about, so that the cord is liable to come in contact with surrounding objects, reinforced flexible cord like that described below for "Portable Lamps" should be provided.

The two conductors which form the cord should be carefully knotted together in both socket and rosette, so as to prevent any strain from coming on the small binding screws in these fittings.

Portable Lamps.

In this class of work the fittings are subjected to much hard usage, and the very best possible construction is therefore necessary. Instead of the ordinary flexible cord made for pendant lamps, a special cord having an extra covering of rubber, reinforced by a tough outer braid, should be used. A list of manufacturers who can supply such cord is given in "Approved Electrical Fittings."

The cord should be securely fastened to the wall or ceiling by a cleat or split knob near the point at which it connects to the rosette or supply wires, so that no strain can come on this connection. (See Fig. 41, page 80.) It should also be knotted inside the socket, as explained above under "Flexible Cord." An approved metal shell socket with an outlet threaded for ⅜ inch pipe should be used, so that the whole cable may be drawn into the socket and still permit the use of a proper socket bushing.

The bulb of an incandescent lamp frequently becomes hot enough to ignite paper, cotton and similar readily ignitible materials, and in order to prevent it from coming in contact with such materials, as well as to protect it from breakage, every portable lamp should be surrounded with a substantial wire guard. Many of the lamp-guards now on the market are very flimsy and utterly worthless.

Waterproof Pendants.

For incandescent lamps in wet places, approved waterproof sockets should be used. These sockets should be suspended by separate, *stranded*, rubber-covered wires, soldered to the socket leads and also to the overhead wires. Where the pendant is over 3 feet long, the wires should be twisted together. The entire weight of the pendant should be borne by cleats or some other independent means, in order to prevent any strain on the connection to the overhead wires. (See Figs. 39 and 40, page 79.)

Arc-Lamps.

"Enclosed arc" lamps having tight inner globes may, in general, be used wherever desired, although in "Especially Hazardous Places," mentioned below, it is believed that the incandescent lamp makes the safer light and is generally as satisfactory. Its use in these rooms is therefore recommended in preference to the arc lamp. Any switches attached to arc lamps, or resistance coils used with them, must be so arranged and protected that dust cannot gather around them and become ignited by a spark from the switch or by overheating of the resistance or magnet coils. Each lamp or series of lamps must be protected by a separate cut-out, and the lamps may be grouped and controlled by switches as desired.

As a matter of regulation it is not advisable to have a very large number of lamps controlled by one switch, as annoying momentary fluctuations in the voltage of the generator may result when the switch is closed or opened.

In general, the use of arc lamps in series on constant-potential systems should be avoided if possible. However, if other arrangements of circuits are impracticable, this may be permitted on low-voltage circuits, provided the lamps are specially designed for this service and are favorably located. (See Rules 21 *d* and 29 *a*, pages 64 and 80.)

Especially Hazardous Places (such as Picker and Carding Rooms, Napping Rooms, Dust Chambers, Etc.).

For incandescent lamps in these more hazardous places, an excellent pendant can be secured by using reinforced flexible cord and a keyless socket with an outlet threaded for ⅜ inch pipe and properly bushed, as advised for "Portable Lamps" on page 18. The cord should be securely supported from the ceiling by a porcelain cleat or split knob, and the two conductors should then be separated and soldered to the overhead circuit. (See Fig. 41, page 80.) The regular "Waterproof Pendant" described on page 19 could also be used. As far as possible cut-outs should not be located in these rooms, but if this cannot be avoided they should be of the plug or cartridge type and should be enclosed in dust-tight wooden cabinets. (See Rule 54, page 108.) If it is desired to control the lights from points in these rooms, it should be done by snap switches, which should be either enclosed in dust-tight cabinets or located where lint and flyings cannot accumulate around them.

Storehouses.

The best and safest light for storehouses is the incandescent lamp. Special care should be taken to so locate and protect the wires that the handling of storage in the building could never derange them. The pendants should be of the type advised above for "Especially Hazardous Places." The cut-outs and switches should be grouped and enclosed in dust-tight wooden cabinets. Strong lamp guards should be provided, as advised for "Portable Lamps" on page 18.

Telephone, Call Bell, and Similar Circuits.

The arrangement of these wires should be as carefully planned as that of the lighting or power circuits. They should be so placed as never to be in the way of fire streams or ladders. Where possible, the signal wires about the yard should be kept entirely away from lighting or power circuits. This avoids the liability of the two systems crossing if breaks occur, and dangerous currents being conducted into buildings over wires ordinarily considered harmless.

Where the arrangement is of necessity such that crosses might occur if wires broke, protectors should be provided near the point where the signal wires enter each building. Protectors should also be provided on all foreign lines, such as public telephone or fire-alarm wires, and on all private lines which are liable to receive lightning discharges.

GENERAL PLAN

GOVERNING THE ARRANGEMENT OF RULES

CLASS A. — **STATIONS AND DYNAMO ROOMS. Includes Central Stations; Dynamo, Motor, and Storage-Battery Rooms; Transformer Sub-Stations; Etc.** Rules 1 to 11.

CLASS B. — **OUTSIDE WORK, all systems and voltages.** Rules 12 to 13 A.

CLASS C. — **INSIDE WORK:** —
General Rules, all systems and voltages. Rules 14 to 17.
Constant-Current Systems. Rules 18 to 20.
Constant-Potential Systems: —

General Rules, *all voltages.* Rules 21 to 23.
Low-Potential Systems, *550 volts or less.* Rules 24 to 34.
High-Potential Systems, *550 to 3500 volts.* Rules 35 to 37.
Extra-High-Potential Systems, *over 3500 volts.* Rules 38 and 39.

CLASS D. — **FITTINGS, MATERIALS, AND DETAILS OF CONSTRUCTION, all systems and voltages.** Rules 40 to 63.

CLASS E. — **MISCELLANEOUS.** Rules 64 to 67.

CLASS F. — **MARINE WORK.** Rules 68 to 83. (As the Factory Mutuals do not enter this class of work, this part of the Code is omitted from this book.)

The Rules are printed in large type, thus: —

c. Must be thoroughly insulated from the ground wherever feasible.

The fine-print notes belonging to the National Electrical Code are in the smaller fine type, thus: —

A high-potential machine which, on account of great weight or for other reasons, cannot have its frame insulated from the ground, should be surrounded with an insulated platform.

The explanatory notes added by the Factory Mutuals are printed in the larger of the fine types, thus: —

By "ground" is to be understood the earth, walls or floors of masonry, pipes of any kind, iron beams, and the like.

GENERAL SUGGESTIONS.

In all electric work, conductors, however well insulated, should always be treated as if they were bare, to the end that under no condition, existing or likely to exist, can a ground or a short-circuit occur, and so that all leakage from conductor to conductor, or between conductor and ground, may be reduced to the minimum.

In all wiring, special attention must be paid to the mechanical execution of the work. Careful and neat running, connecting, soldering, taping of conductors, and securing and attaching of fittings, are especially conducive to security and efficiency, and will be strongly insisted upon.

In laying out an installation, except for constant-current systems, every reasonable effort should be made to secure distribution centres located in easily accessible places, at which points the cut-outs and switches controlling the several branch circuits can be grouped for convenience and safety of operation. The load should be divided as evenly as possible among the branches, and all complicated and unnecessary wiring avoided.

The use of wire-ways for rendering concealed wiring permanently accessible is most heartily endorsed and recommended; and this method of accessible concealed construction is advised for general use.

Architects are urged, when drawing plans and specifications, to make provision for the channeling and pocketing of buildings for electric light or power wires.

RULES

"NATIONAL ELECTRICAL CODE."

CLASS A.

STATIONS AND DYNAMO ROOMS.

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

1. Generators.

a. Must be located in a dry place.

If generators are allowed to become wet, there is likely to be more or less charring or burning of the cotton insulation of the wires, due to the fact that shellaced cotton will conduct electricity when wet. The current leaking over this moist conducting path, the resistance of which is being constantly decreased by the formation of copper salts by electrolytic action, may eventually develop excessive heat or even fusion of some of the metallic parts.

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.

Any generator, if badly designed, improperly handled or overloaded, is liable to produce sparks, which may be of sufficient intensity to set fire to readily inflammable gases, dust, lint, oils and the like.

c. 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.

A high-potential machine which, on account of great weight or for other reasons, cannot have its frame insulated from the ground, should be surrounded with an insulated platform. This may be 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.

In the case of a machine having an insulated frame, if there is trouble from static electricity due to belt friction, it should be overcome by placing near the belt a metallic comb connected with the earth, or by grounding the frame through a resistance of not less than 300,000 ohms.

By "ground" is to be understood the earth, walls or floors of masonry, pipes of any kind, iron beams and the like.

If frame insulation is not provided, a slight fault in the insulation of the magnet or armature coils is likely to ground the electric system, and

1. Generators—*Continued.*

a short-circuit will then occur the instant another ground occurs at any point on the system.

The reason for requiring a *positive* ground wherever frame insulation is impracticable, is to provide a definite path for leak currents and thus prevent them from escaping at points where they might do harm. A good ground can be made by firmly attaching a wire to the dynamo frame and to any *main* water pipe that is thoroughly connected with underground pipes. The wire should not be smaller than No. 6 B. & S. gage and should be securely attached to the pipe by soldering it to a brass plug screwed into a fitting, or by binding it under a heavy split clamp, or by any other equally thorough method. With direct-connected units, the engine or water-wheel would generally furnish a sufficiently good ground.

It is best to provide a solid timber base-frame, even with a wooden floor, for it is difficult to be sure that even a dry floor will furnish perfect insulation, by reason of the many nails driven through it, the pipe hangers likely to be screwed into its under side and the many other possibilities of metallic connection to the ground. For the same reason, care should be taken that the bolts which hold the generator in place do not pass way through the base-frame, so as to come in contact with the floor.

A four-sided framework encloses a space underneath the machine, and as such a space collects lint and dust and is not easily kept clean, a frame consisting merely of two parallel timbers, like that shown in Fig. 14 on page 34, is preferable. The base-frame should raise the generator several inches above the floor level, as a raised frame is more easily kept free from metal dust, dampness, etc., which may afford an opportunity for the escape of current to the ground. A hard and durable finish for the timber can be made by several coats of linseed oil and a finish coat of shellac or hard varnish.

When generators are direct-connected to engines or water-wheels, it is necessary to use an insulating coupling if the frames are to be insulated from the ground. The insulation of such couplings is not entirely reliable, as the vibrations, shocks and constant strain of driving, together with oil and dirt, are very liable to destroy the insulating material.

d. Every constant-potential generator must be protected from excessive current by a safety fuse or equivalent device, of *approved* design, in each lead wire.

These devices should be placed on the machine or as near it as possible.

Where the needs of the service make these devices impracticable, the Inspection Department having jurisdiction may, in writing, modify the requirements.

If this protection is not provided, an accidental short-circuit across the bus-bars or the exposed metal parts of the main switch on the switchboard is liable to result in the burning out of the armature.

e. Must each be provided with a waterproof cover.

This is to protect them from water, dirt, lint, etc., when they are at rest, and is likely to prevent serious water damage to them if a fire at any point causes a thorough wetting down of rooms above them.

f. 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.

The name-plate shows exactly what the machine was designed for. Such information is often of great convenience, and also tends to prevent overrating, either from ignorance or from a desire to magnify the merits of a machine in order to help a sale.

Voltmeters and Ammeters.

A reliable voltmeter should be provided on the switchboard, and it is best to have it so arranged as to show the voltage not only between the wires of opposite polarity, but also between each wire and the earth, thus serving as a very sensitive ground detector. (See Appendix, page 123.)

See also note under Rule 2 *d*, page 26.

1. Generators — *Continued.*

It is also advised that a reliable ammeter be provided with every constant-potential generator, and that it be clearly marked to indicate the full load of the machine. This instrument measures the amount of current given out by the generator and shows instantly if there is any undue load, such as would be produced if too many lamps were put in circuit, or if there was serious leakage of current at any point on the system. It is always desirable to have an ammeter so graduated that a full scale deflection corresponds to the maximum allowable load on the generator, so that when several machines of different sizes are running in parallel, each machine will be doing its share of the work when the ammeter pointers are in similar positions.

2. **Conductors** — *From generators to switchboards, rheostats or other instruments, and thence to outside lines.*

a. Must be in plain sight, or readily accessible.

So that any derangement of the wires or other accident which might happen to them may be quickly noticed and repairs made at once.

Wires from generator to switchboard may, however, be placed in a conduit in the brick or cement pier on which the generator stands, provided that proper precautions are taken to protect them against moisture and to thoroughly insulate them from the pier. If lead-covered cable is used, no further protection will be required, but it should not be allowed to rest upon sharp edges which in time might cut into the lead sheath, especially if the cables were liable to vibration. A smooth runway is desired. If iron conduit is provided, double braided rubber-covered wire (see Rule 47, page 91) will be satisfactory.

Main conductors in immediate connection with the source of power must be treated as especially dangerous, because the whole capacity of the system would be concentrated in them should an arc start or an accidental short-circuit be made between them.

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

Bus-bars may be made of bare metal.

Rubber and weatherproof insulations ignite easily and burn freely. Where a number of wires are brought close together, as is generally the case in dynamo rooms, especially about the switchboard, it is therefore necessary to surround this inflammable material with a tight, non-combustible outer cover. If this is not done, a fire once started at this point would spread rapidly along the wires, producing intense heat and a dense smoke. Where the wires have such a covering and are well insulated and supported, using only non-combustible materials, it is believed that no appreciable fire hazard exists, even with a large group of wires.

Fig. 8, page 26, illustrates very well the need of a slow-burning outer covering on the wires where they are grouped.

It is also recommended that all live parts of the switchboard, such as bus-bars and other conductors, be protected against accidental contact as far as practicable by suitable insulation, which shall be "flame proof" or "slow-burning" and designed to withstand a reasonable amount of abrasion. The chances of accidental short-circuits may thereby be greatly reduced. Insulated cable for bus-bars and connections is excellent for this purpose. However, the conductors could be wrapped or taped if this should be found more convenient, but this method should never be used unless it can be done well. Due to the possibly rather low insulating properties of most fireproofing compounds as used, special precautions would be necessary on high-voltage circuits to prevent current leakage over the outer fireproofed covering. A slow-burning wire is also advised for connections between the field rheostat and its contact-plate when the two are separated, as is generally the case with large alternating-current generators. The only practicable way to run the large number of wires, 50 or more, which are often necessary is to bunch them, and the need of a slow-

2. **Conductors** — *Continued.*

burning insulation here is very evident. The maximum voltage between any two of the wires is rarely over 300, so that approved slow-burning wire (see Rule 42, page 88) is recommended for this purpose. It, however, would be a good plan to subdivide these wires, as far as practicable, into several groups and insulate each group on porcelain, thus reducing the maximum voltage between wires in contact.

FIG. 8.
LARGE GROUP OF WIRES, WELL SUPPORTED.

c. Must be kept so rigidly in place that they cannot come in contact.

It is often necessary, also, to protect the wires against accidental blows from belts, or from ladders, etc., in the hands of careless workmen. This may be done in about the same manner as is recommended for wires on side walls. (See pages. 69–72.)

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.

In wiring switchboards, the ground detector, voltmeter and pilot lights must be connected to a circuit of not less than No. 14 B. & S. gage wire that is protected by a standard fuse block. This circuit is not to carry over 660 watts.

3. Switchboards.

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

Special attention is called to the fact that switchboards should not be built down to the floor, nor up to the ceiling. A space of at least 10 or 12 inches should be left between the floor and the board, and 3 feet, if possible, between the ceiling and the board, in order to prevent fire from spreading from the switchboard to the floor or ceiling, and also to prevent the formation of a partially concealed space, very liable to be used for the storage of rubbish, oily waste, etc.

Great care in designing and locating a switchboard is necessary for several reasons: the rheostats, measuring instruments, fuses, etc., are possible sources of fire; there is a considerable number of bare live parts on the ordinary board which afford good opportunity for accidental short-circuits; and there is frequently a large amount of power available at the board to quickly follow up any trouble at this point.

b. Must be made of non-combustible material, or of hard wood 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.

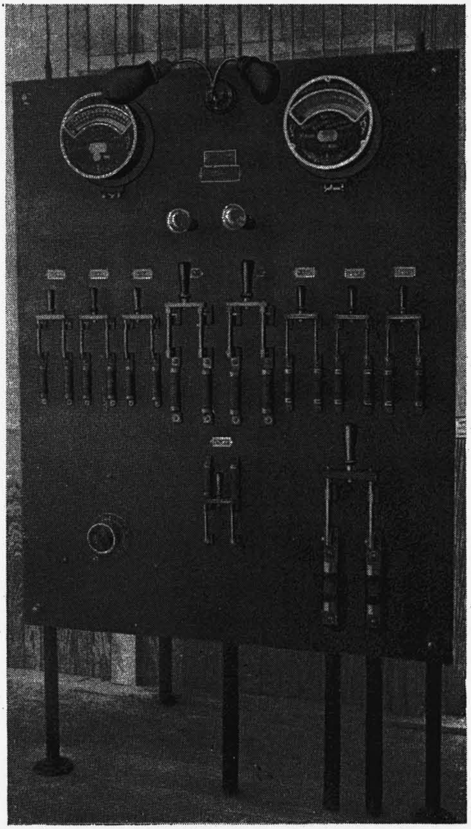


FIG. 9.

WELL-ARRANGED SLATE SWITCHBOARD.

Switchboards of slate or marble are now mostly used. A slate board complete is but little more expensive than a properly wired and equipped wooden board in skeleton form. The non-combustible board is undoubtedly preferable, and is therefore strongly recommended, especially for the larger equipments.

The slate switchboard shown in Fig. 9 is an excellent example of a well-arranged modern board, equipped with all the necessary apparatus for controlling the output of one generator. Attention is called to the use of enclosed fuses on this board, also the location of the ground detector lamps, which brings them near together, so that any difference in brilliancy may be readily noted. All of the wiring on the back of this board has slow-burning weatherproof insulation (see Rule 42, page 88), thus securing the slow-burning feature recommended in Rule 2 *b*, page 25.

c. Must be accessible from all sides when the connections

3. **Switchboards** — *Continued.*

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 should be a clear space of at least 18 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. The space back of the board should not be closed in, except by a grating or netting, either at the sides, top or bottom, as such an enclosure is almost sure to be used as a closet for clothing or for the storage of oil cans, rubbish, etc. An open space is much more likely to be kept clean and is more convenient for making repairs, examinations, etc.

This point is well illustrated by Fig. 10, which shows the back of a slate switchboard, neatly wired and well located. Every part of this board is easily accessible, and all necessary repairs can be made with very little chance of deranging the wires. By insulating the bus-bars and other bare conductors, as mentioned in Rule 2 *b*, page 25, the liability of accidental short-circuits at this point could be largely avoided.

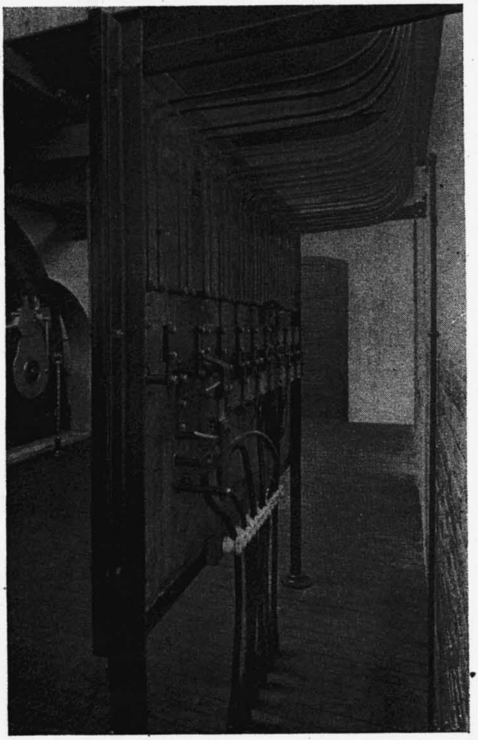


FIG. 10.
SLATE SWITCHBOARD, NEATLY WIRED AND WELL LOCATED.

d. Must be kept free from moisture.

Water on a switchboard is liable to produce serious trouble, as it is almost certain to start leaks over the surface of the insulating coverings on the wires and over the board itself; for water-soaked insulators, or a film of water on a non-absorptive insulator, like glass, porcelain or hard rubber, will conduct electricity to some extent. By electrolytic action this leakage current will form salts of copper over the surface of the insulating parts, and as these salts are good conductors, the leakage current will be increased, resulting in the inevitable destruction of the weakest part, be it insulation, wire or dynamo. Under such conditions there would also be great danger of the attendant receiving severe shocks.

e. On switchboards the distances between bare live parts of opposite polarity must be made as great as practicable, and must not be less than those given for tablet-boards. (See Rule 53 A, page 107.)

4. **Resistance Boxes and Equalizers.**

(*For construction requirements, see Rule 60, page 115.*)

a. Must be placed on the switchboard or, if not thereon, at a distance of at least a foot from combustible material or

4. **Resistance Boxes and Equalizers**— *Continued.*

separated therefrom by a non-inflammable, non-absorptive, insulating material, such as slate or marble.

The attachments of the separating material to its support and to the device must be independent of each other, and the separating material must be continuous between the device and the support; that is, the use of porcelain knobs will not be accepted.

Resistance boxes should be considered as stoves, which under some conditions may become red hot, and from which drops of heated metal may fall, or even be thrown some distance.

Motor-starting rheostats, arc lamp compensators, electric heaters and the like would all come under this rule unless so designed as to make these precautions unnecessary for the desired safety.

b. Where protective resistances are necessary in connection with automatic rheostats, incandescent lamps may be used, provided that they do not carry nor 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.

5. Lightning Arresters.

(*For construction requirements, see Rule 63, page 117.*)

a. Must be provided on each wire of every overhead circuit connected with the station.

It is recommended to all electric light and power companies that arresters be connected at intervals over systems in such numbers and locations as to prevent ordinary discharges entering (over the wires) buildings connected to the lines.

The kind and degree of protection necessary depend largely on circumstances. A short outdoor line from one mill building to another will often require nothing, while a long overhead line through an open exposed country will generally need the most careful engineering to secure reasonable freedom from lightning disturbances.

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 building.

Station arresters should generally be placed in plain sight on the switchboard.

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.

The arresters should be accessibly located, so that they may be easily examined from time to time, and should always be isolated from combustible materials, as sparks are sometimes produced when lightning is discharged through them. The switchboard does not necessarily afford the only location meeting these requirements; in fact, if the arresters could be located in a safe and accessible place away from the board, this should be

5. **Lightning Arresters**— *Continued.*

done, for in case the arrester should fail or be seriously damaged there would then be less chance of starting arcs on the board.

Kinks, coils, sharp bends, etc., may offer enormous resistance to a lightning current, possibly preventing its discharge to ground through the arrester and causing it to leave the wires at some other point, where it might do considerable damage.

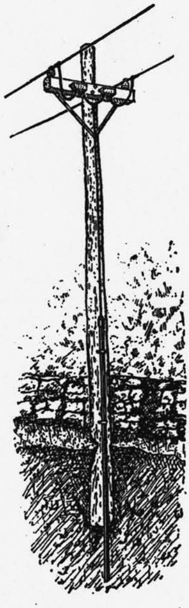


Fig. 11.
Ground Connection for Line Lightning Arrester.

c. Must be connected to 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.

It is often desirable to introduce a choke coil in circuit between the arresters and the dynamo. In no case should the ground wire from a lightning arrester be put into an iron pipe, as this would tend to impede the discharge.

Fig. 11 shows a convenient way of making a ground for a line arrester, it being assumed that there are a number of arresters distributed along the line, so that the protection of the system does not depend entirely on this one ground. In general, it is desirable to place from two to five arresters per mile, depending on the exposure and general situation of the line. In locating arresters, preference should be given to those places where earth which is always damp can be most easily and surely reached.

The ground connection shown in the cut consists of galvanized iron pipe with a nominal outside diameter of at least 1 inch. It should be in one piece if possible, and should be driven into the ground at least 8 feet, or even further if *permanently* damp earth is not found at that depth. If, however, it should prove impossible to drive the pipe far enough to reach earth that would surely be permanently damp, a small hole should be dug around it to a depth of 4 or 5 feet, and it should then be driven as far as possible and the hole filled with crushed coke or charcoal about pea size. This improves the connection between the pipe and the earth, thus tending to make up for the lack of moisture.

The pipe should extend above the ground for a distance of at least 7 feet, and the ground wire should be soldered to a brass plug screwed with considerable force into a coupling at the top of it. The wire must never be put inside the pipe, as this would tend to impede the lightning discharge. Both pipe and wire should be firmly fastened to the pole with strong staples, so as to guard against the ground connection being broken. The wire should be kept as straight as possible for the reason given in the note to Rule 5 *b*, on page 29, the only bend in it being that necessary to form the drip loop.

For a group of arresters, such as might exist in a station, or in a lightning arrester house at the end of a long line, a more elaborate ground would be desirable, and for this work an excellent connection can be made in the manner shown in Fig. 12. The lightning arrester, choke coil, switch, etc., shown in the cut may be considered to represent one of several sets, each wire entering the house being fully equipped in the same manner. A separate wire may be carried from each arrester to the copper plate, or two main wires, not smaller than No. 0 B. & S. gage each, may be used, the ground wires from the separate arresters running in the most direct line possible to these mains and being firmly soldered to them.

5. Lightning Arresters—*Continued.*

The copper plate and coke or charcoal would ordinarily make a sufficiently good ground, but it is desirable to also connect to an underground water pipe, if one is near. There is no danger of getting too good a ground. The surest way to secure a good connection with a pipe is to tap a hole part way through it, and forcibly screw into the hole a brass plug to which the wire has been soldered. The joint should then be covered with waterproof paint and taped, to prevent corrosion. It is best to connect to several lengths of pipe, as the lightning discharge is thus distributed over several points. A better ground is also obtained, as pipe joints are liable to offer considerable resistance. It is not desirable, however, to connect to pipes which enter and ramify through a building, such as sprinkler pipes, at a point nearer than 50 to 75 feet from the building; neither is it best to have the ground connection for a large bank of arresters located very near buildings or near pipes which enter them.

The lightning arresters should be inspected frequently, to be sure that they are in proper condition. This is especially necessary during the summer season, when lightning storms are most liable to occur. It is also of the greatest importance to maintain an excellent ground connection for the arresters, as the efficiency of the protection is absolutely dependent upon this feature. The entire ground connection should therefore be uncovered and carefully examined at least once a year, preferably in the spring, in order to positively know that the connection has not been impaired by corrosion or other accident and that the earth in the vicinity of the ground plate or pipes is still damp, so that the equipment is in proper shape for the season's work.

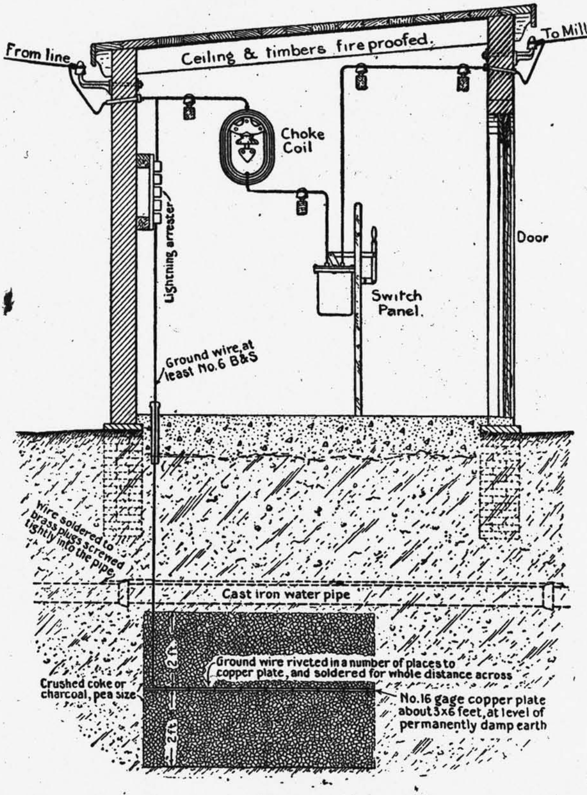


FIG. 12.

LIGHTNING ARRESTER HOUSE WITH GROUND CONNECTION.

Choke coils and lightning arresters are arranged in different ways, depending on the exact conditions in any given case. Fig. 12, however, shows the usual arrangement, although two or more such combinations of choke coil and arrester are sometimes connected in series in each wire; again, a number of choke coils may be placed in series back of a single arrester, etc. The choke coil acts like a dam and tends to prevent light-

5. **Lightning Arresters** — *Continued.*

ning currents from passing through it, thus compelling them to go through the arrester to the ground. Choke coils are made in various forms but practically all consist of a coil of several turns of insulated conductor. As little combustible material as possible should be used in their construction and also for their supports.

Where the house contains considerable value in arresters, choke coils, switches, etc., it should be built of brick with a fireproofed plank roof and concrete floor, so as to reduce the chances of a fire to a minimum. The plank roof is suggested instead of concrete or brick arched construction because it is less expensive and is believed to be good enough in most cases if properly protected. Suggestions for fireproofing such exposed wooden surfaces are given on page 5, with reference to similar roofs for power houses. For very large equipments, fireproof construction should be used throughout the building. Where brick is not considered necessary, a wooden building of plank and timber is advised, and all light and flimsy woodwork should be avoided.

The arrester house would generally be an excellent place for the emergency switch, as this building would usually be located well away from the other buildings and would thoroughly protect the switch against the weather. In such cases, therefore, the switch shown should be arranged for this purpose. For suggestions regarding the emergency switch, see note to Rule 22 *a* on page 65.

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* metal cans and removed daily.

Approved waste cans shall be made of metal, with legs raising the can 3 inches from the floor, and with self-closing covers.

7. Testing of Insulation Resistance.

a. All circuits, except such as are permanently grounded in accordance with Rule 13 A, page 52, 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.

The ground detectors most commonly used are fully explained and illustrated in the Appendix, page 123.

See also note under Rule 2 *d*, page 26.

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

c. Data obtained from all tests must be preserved for examination by the Inspection Department having jurisdiction.

These rules on testing are to be applied at such places as may be designated by the Inspection Department having jurisdiction.

8. Motors.

a. 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,

8. **Motors** — *Continued.*

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.

A high-potential machine which, on account of great weight or for other reasons, cannot have its frame insulated, should be surrounded with an insulated platform.

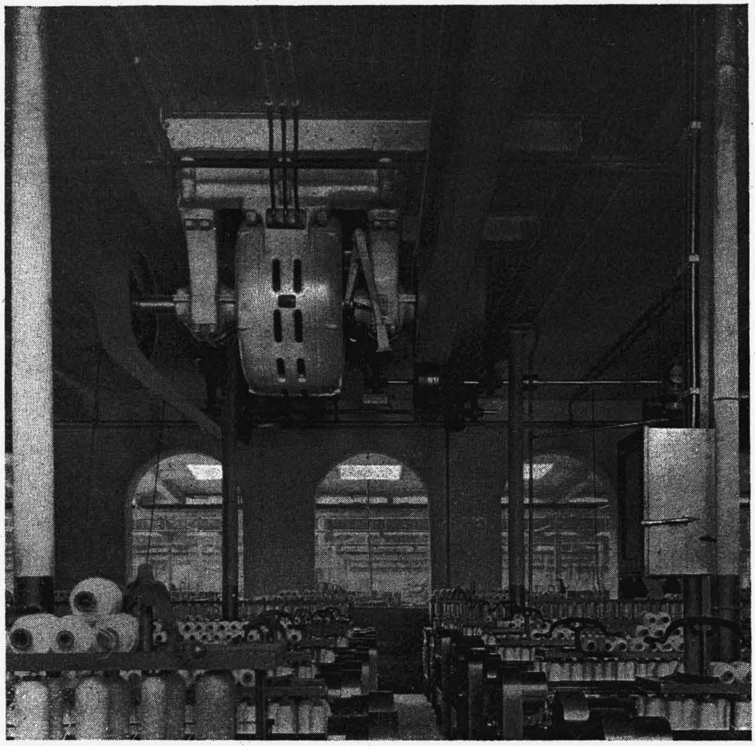


FIG. 13.
INDUCTION MOTOR ON CEILING, WITH STARTING SWITCH ENCLOSED IN CABINET AND OPERATED BY OUTSIDE HANDLE.

This may be 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.

In the case of a machine having an insulated frame, if there is trouble from static electricity due to belt friction, it should be overcome by placing near the belt a metallic comb connected to the earth, or by grounding the frame through a resistance of not less than 300,000 ohms.

For the same reasons that similar requirements were made for generators, in the note to Rule 1 *c* on page 23. The base-frame shown in Fig. 14, page 34, is an excellent example.

It is very common to suspend motors from the ceiling, as shown in

8. **Motors** — *Continued.*

Fig. 13, page 33, and in Figs. 15 and 16, or to locate them on raised platforms swung from the ceiling or supported from below, as shown in Fig. 17 on page 36. Any one of these methods saves floor space and frequently prevents an accumulation of oil and dirt around the machine, besides reducing the liability of accidents to persons or machinery.

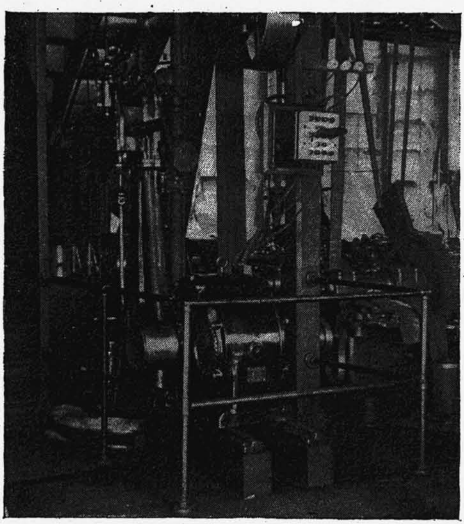


FIG. 14.

INDUCTION MOTOR AND AUTO-STARTER SURROUNDED BY PIPE RAILING.

b. Must be wired with the same precautions as required by rules in Class "C," for wires carrying a current of the same volume and potential.

The motor leads or branch circuits must be designed to carry a current at least 25% greater than that for which the motor is rated, in order to provide for the inevitable occasional overloading of the motor, and the increased current required in starting, without overfusing the wires.

The use of voltages above 550 is rarely advisable or necessary, and will only be approved when every possible safeguard has been provided. Plans for such installations should be submitted to the Inspection Department having jurisdiction before any work on them is begun.

c. Each motor and resistance box must be protected by a cut-out and controlled by a switch (see Rule 17 *a*, page 60), said switch plainly indicating whether "on" or "off." With motors of ¼ H. P. or less, on circuits where the voltage does not exceed 300, Rule 21*d*, page 64, must be complied with, and single pole switches may be used as allowed in Rule 22 *c*, page 67. 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.

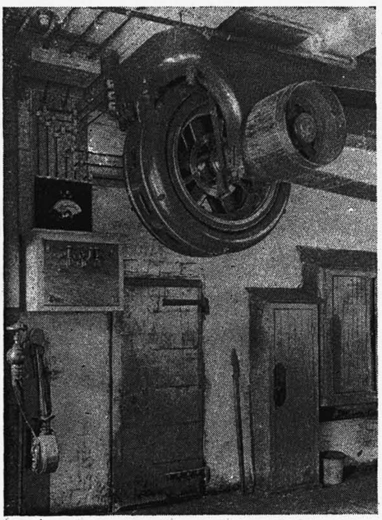


FIG. 15.

INDUCTION MOTOR ON CEILING.

8. **Motors** — *Continued.*

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.

The switch is necessary for entirely disconnecting the motor when not in use, and the cut-out to protect the motor from excessive currents due to accidents or careless handling when starting. An automatic circuit-breaker disconnecting all wires of the circuit may, however, serve as both switch and cut-out.

Fig. 15 shows an automatic circuit-breaker used in this way for both switch and cut-out.

d. Must have their rheostats or starting boxes located so as to conform to the requirements of Rule 4, page 28.

The use of circuit-breakers with motors is recommended, and may be required by the Inspection Department having jurisdiction.

To be safe, a starting rheostat should have as great a carrying capacity as the motor itself, or else the arm should have a strong spring-throw attachment so arranged that it cannot remain at any intermediate position unless purposely held there. Specifications governing the construction of rheostats are given in Rule 60, page 115.

Rheostats and auto-starters should be treated about the same as knife-switches, and in all wet, dusty or linty places, should be enclosed in dust-tight, fireproofed cabinets. If a special motor room is provided, the starting apparatus and safety devices should be included within it. Where there is any liability of short-circuits across their exposed live parts being caused by accidental contacts, they should either be enclosed in cabinets or else a railing should be erected around them to keep unauthorized persons away from their immediate vicinity.

FIG. 16.

ENCLOSED DIRECT-CURRENT MOTOR, WITH SWITCH, FUSES, RHEOSTAT, ETC. ENCLOSED IN CABINET.

Iron pipe makes a neat and substantial railing for this purpose, and Fig. 14 shows an example of such an arrangement. These precautions would, of course, be unnecessary where the apparatus is included with the motor in a special motor room, such, for example, as is shown in Fig. 18, page 37.

8. **Motors** — *Continued.*

Auto-starters which have tight casings enclosing all current-carrying parts would, of course, not require the cabinet nor railing.

Starting apparatus enclosed in cabinets is shown in Fig. 16, page 35, and in Fig. 17.

The commercial practice is to make starting rheostats as small as possible, because the time required to start a motor is ordinarily so short that the rheostat will not be dangerously heated by the starting current. If, however, the current is allowed to flow through it too long, there is excessive heating and often fusion of some of its parts. It is to be noted that the safety fuses required by the motor will readily carry current enough to melt the rheostat, so that the latter is not at all protected by the fuses.

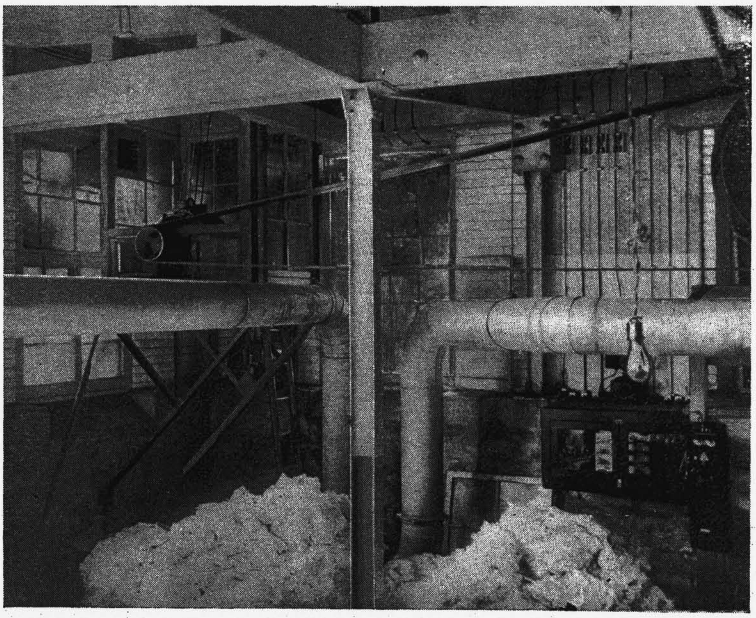


FIG. 17.

MOTOR ON SHELF, ENCLOSED IN GLASS CASE AND REACHED BY LADDER, WITH AUTO-STARTER IN CABINET.

e. Must not be run in series-multiple nor multiple-series, except on constant-potential systems, and then only by special permission of the Inspection Department having jurisdiction.

The objection to combinations of this character is that the cutting-out of one motor, by accident or carelessness, may subject the others to a current or voltage greater than that for which they are designed; and if this occurs, and the protecting devices fail, as sometimes happens, there is very likely to be severe arcing, or a burn-out.

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.

From the nature of the question, the decision as to what is an approved case must be left for the Inspection Department having jurisdiction to determine in each instance.

8. **Motors** — *Continued.*

When it is necessary to locate a motor in the vicinity of combustibles or in wet or very dusty or dirty places, it is generally advisable to surround it with a suitable enclosure.

The sides of such enclosures should preferably be made largely of glass, so that the motor may be always plainly visible. This lessens the chance of its being neglected and allows any derangement to be at once noticed.

If possible, the enclosure should be large enough to permit the attendant to enter it and easily get at any part of the apparatus, and this would generally mean a small room, such as is shown in Fig. 18. If the motor is suspended from the ceiling, a floor could generally be constructed below it and the four sides of this elevated motor room could be built mainly of windows. Ready access to the room could be secured by means of a short flight of stairs or a ladder. This can also be done where the motor is supported on an elevated platform, as shown in Fig. 17. Some method of ventilating these motor rooms should generally be pro-

FIG. 18.

WELL-ARRANGED MOTOR ROOM.

vided, especially in the case of large machines, in order to prevent excessive rise in temperature of the air in the room, which might cause overheating of the apparatus.

With alternating-current motors having no brushes, the enclosure would generally be unnecessary, especially when suspended from the ceiling, as shown in Figs. 13 and 15, pages 33 and 34. When located on the floor, it would often be advisable to surround the machine by a substantial pipe rail to keep people from passing too near it, and Fig. 14, page 34, is an excellent illustration of such a case.

g. Must, when combined with ceiling fans, be hung from

8. **Motors**—*Continued.*

insulated hooks, or else there must be an insulator interposed between the motor and its support.

For the same reasons as given in the note to Rule 1 *c*, page 23.

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.

For the same reasons as given in the note to Rule 1 *f*, page 24.

9. Railway Power Plants.

a. Each feed wire, before it leaves the station, must be equipped with an *approved* automatic circuit-breaker (see Rule 52, page 101) or other device, which will immediately cut off the current in case of an accidental ground. This device must be mounted on a fireproof base, in full view and reach of the attendant.

A magnetic circuit-breaker is preferable to a fuse, as it acts more quickly, is more reliable, and can be more quickly and safely replaced.

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 dynamo generators developing the same difference of potential.

Charged storage batteries have in them at all times a large amount of stored energy, and should therefore be treated as carefully as generators of similar output.

b. Storage battery rooms must be thoroughly ventilated.

The action of the current in charging the battery liberates at times large quantities of hydrogen and oxygen, and if these should accumulate in the right proportions they would form an explosive mixture which might be exploded by any accidental spark.

c. Special attention is called to the rules for wiring in rooms where acid fumes exist. (See Rules 24 *i* to 24 *k*, page 73.)

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

The battery needs to be insulated for the same reasons as given in the note to Rule 1 *c*, page 23, and nothing but glass, porcelain and similar materials will retain their insulating properties when exposed to the action of the water and acid freely used about storage batteries.

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

Reduction of the cross-section of the connections by corrosion would probably cause them to be burned out by the normal current of the battery.

11. Transformers.

(*For construction requirements, see Rule 62, page 117.*)
(*See also Rules 13, 13 A and 36, pages 50, 52 and 84.*)

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.

If the insulation in a transformer breaks down, considerable heat is likely to be developed. This would cause a dense smoke, which might be mistaken for a fire and result in water being thrown into the building, and a heavy loss thereby entailed. Moreover, with oil-cooled transformers, especially if the cases are filled too full, the oil may become ignited and boil over, producing a very stubborn fire.

Class B.

OUTSIDE WORK.

All Systems and Voltages.

12. **Wires.**

a. Service wires must have an *approved* rubber insulating covering. (See Rule 41, page 86.) Line wires, other than services, must have an *approved* weatherproof or rubber insulating covering. (See Rules 41 and 44, pages 86 and 89.) All tie wires must have an insulation equal to that of the conductors which they confine.

In risks having private generating plants, the yard wires running from building to building are not generally considered as service wires, so that rubber insulation will not be required.

The requirement for rubber-covered service wires refers especially to taps from public lines, which are supplied from transformers connected to high-voltage primary circuits or are liable to become crossed with high-voltage wires, and which therefore need the best insulation obtainable.

b. Must be so placed that moisture cannot form a cross connection between them, 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.

To prevent water from forming a short-circuit, as well as to guard against actual contact produced by the swaying of the wires by the wind.

c. Must be at least 7 feet above the highest point of flat roofs and at least 1 foot above the ridge of pitched roofs over which they pass or to which they are attached.

Roof structures are frequently found which are too low or much too light for the work, or which have been carelessly put up. A structure which is to hold the

Fig. 19.

Substantial Wooden Roof Structures.

wires a proper distance above the roof in all kinds of weather must not only be of sufficient height, but must be substantially constructed of strong material.

12. **Wires** — *Continued.*

This rule is intended to insure that under no conditions could the wires sag and touch the roof; and also that persons walking on the roofs could not come into accidental contact with them.

Fig. 19 shows two good examples of durable wooden roof structures holding the wires well out of reach of persons on the roof. Fig. 20 shows a roof structure made of iron rods or pipes. This form of construction can easily be made sufficiently strong, and presents a somewhat neater appearance than the timber frame. The metal work should, of course, be kept painted to protect it against corrosion.

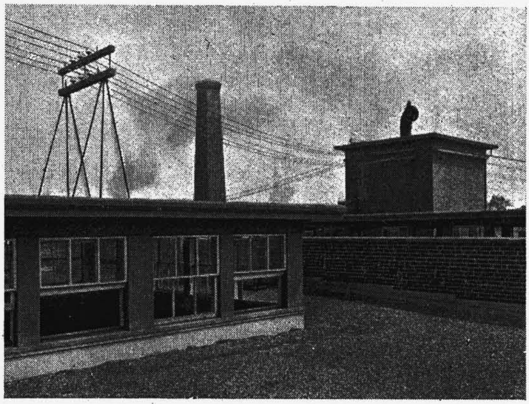


FIG. 20.
IRON PIPE ROOF STRUCTURE.

d. Must be protected by dead insulated guard irons or wires from possibility of contact with other conducting wires or substances to which current may leak. Special precautions of this kind must be taken where sharp angles occur, or where wires of any other systems might possibly come in contact with electric light or power wires.

Crosses, when unavoidable, should be made as nearly at right angles as possible.

If these guards are not provided, the breaking or sagging of a wire may result in contacts which might charge one set of wires with a higher voltage than that for which they were designed, and thus be liable to cause fire or endanger life.

e. Must be supported on petticoat insulators of glass or porcelain. Porcelain knobs or cleats or rubber hooks will not be approved.

The surface of porcelain knobs or cleats is not free from moisture during a rain, and they are, therefore, of practically no use as insulators in wet weather. A petticoat insulator, like those shown in Fig. 21, page 42, will nearly always have a dry space underneath its umbrella-like lower edge, and even if not dry, the length of the path offered to an escaping current is so great that the leakage would be small.

f. 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, even if made with some form of patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these rules.

An unsoldered joint is liable to become loosened or corroded, in either of which events the contact between the wires would become imperfect.

12. **Wires** — *Continued.*

This would cause heating at the joint and might result in the wire being completely melted off and a dangerous arc being formed at the break. A good mechanical joint is required for strength, should the soldering give way or become corroded by traces of acid in the soldering fluid used.

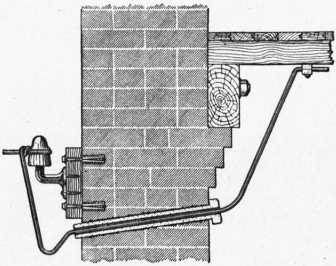


FIG. 21.
ENTRANCE BUSHING AND DRIP LOOP.

g. 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.

Fig. 21 shows the proper arrangement of drip loop, bushing, etc., for wires entering buildings from out of doors. The insulator should be supported on a stout arm, which, for heavy wires or long spans, may need to be held in place by bolts passing entirely through the wall, rather than by expansion bolts, as shown in the sketch. With a very thick wall, the method of bushing shown in Fig. 31, page 56, could be used. In that case, however, some means should be provided to prevent the lower porcelain tube from slipping out of the iron pipe.

h. Telegraph, telephone and other signal wires (see Rule 64, page 118) must not be placed on the same cross-arm with electric light or power wires, and when placed on the same pole with such wires, the distance between the two inside pins on each cross-arm must not be less than 26 inches.

This distance between the two inside pins is necessary to allow a man to safely pass between the wires and reach the cross-arms above.

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

Any breakdown of insulation between the conductor and the sheath makes the cable practically a bare live wire, the dangerous condition of which is obvious. The ground connection required by this section keeps the sheath at the potential of the earth and prevents a flow of current from the sheath at any other point than through the ground wire, which should be of sufficient size and so well connected to the sheath and to the earth that it could safely carry the current necessary to melt the fuses protecting the cable.

Trolley Wires.

j. 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.

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

l. 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 particu-

12. **Wires** — *Continued.*

lar section to prevent its interfering with the work of the firemen. This rule also applies to feeders.

This requirement applies principally to street railways.

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

Guard wires should be insulated from the ground and should be electrically disconnected in sections of not more than 300 feet in length.

In Factory Mutual work, trolley wires must not be carried into buildings until special permission has been given and the best method of running and protecting the wires decided upon

Ground Return Wires.

n. 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 25 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, they be connected by conductors arranged so as to prevent, as far as possible, current flow from the pipes into the ground.

12 A. Constant-Potential Pole Lines, over 5000 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.

It is evident that this is the very best way to guard against the accidental crosses above mentioned, and, therefore, it is strongly urged that every reasonable effort be made to secure the arrangement of the circuits.

12 A. **Constant-Potential Pole Lines, over 5000 Volts** — *Continued.*

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 signalling 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.

It will be readily seen that if the taller pole should break near the ground and should fall toward the lower line, the upper line would strike the lower one unless the distance between the two lines was at least as great as the height of the taller pole.

It would be practically impossible to so arrange and guard the two sets of wires, if on the same line of poles, that all liability of contact between the wires would be absolutely avoided, and, therefore, separate pole lines should be provided wherever possible.

An exception to this rule which must frequently be made is the case of the signaling wires of the electric company, since an additional pole line for these circuits would often be impracticable. However, it should be noted that these wires enter but comparatively few buildings, which, moreover, in most cases, are already subject to the hazard of the high-voltage current, and the owners appreciate perhaps more fully the dangers and safeguards needed under the conditions. Special precautions, however, should be taken regarding the installation and location of wires and instruments so that these could be burned out without setting fire to the surroundings. Danger to life when handling these telephones should also not be overlooked, but should be guarded against in every way possible, even from the fire standpoint, as accident to the attendant might prevent the prompt cutting off of current in case of trouble on the line.

c. Where such lines must necessarily be carried nearer to other pole lines than is specified in § *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 3 feet above the other wires.

This arrangement of circuits should never be adopted unless it is impossible to do otherwise. Where the two lines *must* be run on the same poles, the importance of heavy substantial line construction as above outlined, cannot be too strongly emphasized.

With the high-pressure wires above the others, there will be far less danger to the wireman who may find it necessary frequently to work on the lower-voltage circuits. This relative location of the transmission line would also be preferable if these wires were larger than the others, as they would be less liable to break.

A separation between the high-pressure and low-pressure wires of say 5 feet would be preferable to that of 3 feet above mentioned, wherever this greater distance can be secured.

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

Whenever 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

12 A. **Constant-Potential Pole Lines, over 5000 Volts**— *Continued.*

or to standard transposition insulators, and the line completed by loops.

The object of these end-insulator guards is to prevent the line wire slipping over the end of the cross-arm, in case it becomes loosened from its supports, and falling upon the lower wires. Fig. 22 shows one form of such guard, consisting of a strong wire looped over the live wire and securely fastened to the cross-arm, the corners of which are cut to receive the wire so that it cannot be pulled off from the end of the arm or get out of place and touch the line wire. Another form of guard is shown in Fig. 25, page 47, which consists of a flat bar solidly bolted to the framework or cross-arm.

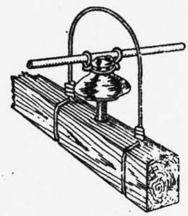


FIG. 22.
END-INSULATOR GUARD.

The dimensions and strength of the guards would depend on the existing conditions, such as voltage of circuit, size of line wire, whether on straight runs or at curves, etc. In any case, they should be of such design that they could resist the strain which may be put upon them at time of accident, and the upright bar form of guard should be of such length that the line wire would not be liable to jump over it. This would probably require that the bar extend at least 6 inches above the level of the wires. With the loop form, the radius should generally be at least 4 inches.

Fig. 23 shows a transposition insulator wired as outlined in above rule. In case the wire should break on either side of the cross-over span, this arrangement would prevent the wire from being drawn over the insulator due to the weight of the wire of the cross-over span, which otherwise might occur and result in contact with the high-pressure wires below. The insulator pins should, of course, be sufficiently strong to resist the strain from the cross-over span under the above conditions. The loop connections would generally be made with a McIntyre sleeve or equivalent.

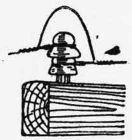


FIG. 23.
TRANSPOSITION INSULATOR.

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.

Fig. 24 illustrates the above method of crossing of high-pressure and low-pressure wires. In the sketch, a high-voltage transmission line crosses a telephone line at a country road. In this case, unless both poles of the cross-over span are set very near the telephone line, the minimum length of the span is limited by the width of the road and the highway regulations and has been taken as 25 feet for this example. Assuming the height of the telephone line to be 20 feet, it is evident that the pole at the end of the cross-over span nearest the telephone line must be of sufficient height to raise the transmission line at least 45 feet above ground, in order that none of these upper wires, breaking at a pin on the other pole, can swing and touch the lower wires. The pole on the opposite side of the road is shown somewhat shorter, which of course is permissible and would still prevent contact between the two lines, even though the break should occur at a pin on the taller pole. To avoid any chance of a wire in the span to the left of the cross-over span breaking and whipping back or being blown back against the lower wires, an additional pole has been shown about 25 feet from the tall pole.

Therefore, unless the tall pole should fall or its cross-arm burn or

12 A. **Constant-Potential Pole Lines, over 5000 Volts** — *Continued.*

break off, there is practically no chance of contact between the two lines. Such accidents to this pole could be largely avoided by using heavy substantial stock and carefully selected insulators, or by using iron cross-arms with iron pins thoroughly grounded, or in fact by making the entire pole structure of metal and grounding it. This latter construction would be stronger and probably more durable than the wooden pole, and the grounded metal work would surely prevent the burning off of the arms or pole in case of a broken insulator, etc., as the system would be immediately grounded and the transmission line shut down. The pole, whether of wood or iron, could also be guyed, if thought necessary, in order to secure greater strength. The pole should be carefully inspected sufficiently often to be sure that it is maintained in proper condition.

Care should be taken that the two poles on either side of the tall pole are not so short that when the wires are drawn tight the insulators or tie wires would be subjected to an undue upward tension. Any change in direction of these wires should be gradual, as sharp turns are almost sure to weaken the pole line. This "three-pole" cross-over, as it might be called, would of course be just as applicable where the crossing came in the open country instead of at a road.

A suggestion, somewhat in line with the construction above outlined and already briefly alluded to, has recently been made that the two poles

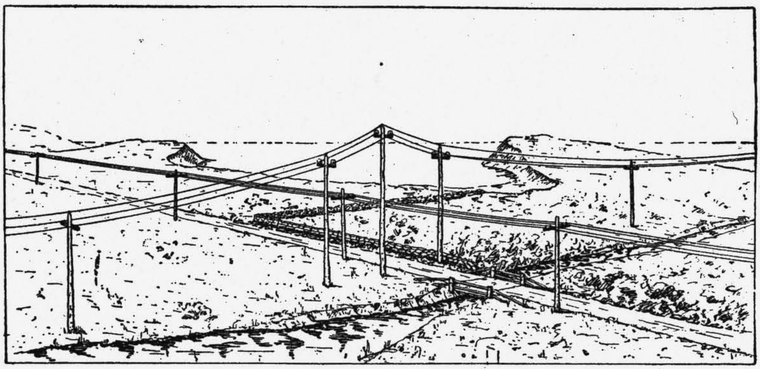


FIG. 24.

HIGH-PRESSURE LINE CROSSING OTHER LINES.

of the cross-over span be set fairly near the lower line, making the span as short as practicable; then in order to protect against an upper wire breaking in either of the adjacent spans, it is suggested that a grounded metal guard be built out from each of the taller poles, just under the upper wires on the side away from the cross-over span, and so proportioned that the wire in falling would strike it before the wire could touch the lower line. By thus grounding the high-tension line, it is expected that a dangerous rise of voltage on the low-potential circuits would be prevented.

Existing conditions in any particular case will largely determine which arrangement is best or in what respects modifications are advisable. The above suggestions, however, are given here, as they all have merit and are believed to be applicable to several different conditions which possibly may be most frequently met in practice.

Where crosses must occur, it is believed that, as a rule, the general style of crossing above outlined is preferable to that using a joint pole or interposed screen.

2. A joint pole may be erected at the crossing point, the high-pressure wires being supported on this pole at least 3 feet above the other wires. Mechanical guards or supports must then be provided, so that in case of the breaking of any upper

12 A. **Constant-Potential Pole Lines, over 5000 Volts** — *Continued.*

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 aërial 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.

A suggestion for a joint pole where a high-pressure transmission line crosses several telephone lines is illustrated in Fig. 25. The sketch shows a very strong and substantial wooden framework bolted to the top of a heavy pole and used to support the high-potential insulators for the transmission line and also those for the guard wires. The end insulator guards of flat iron bars are also bolted to this framework. The details of construction may be readily seen in the sketch. The telephone wires are shown 5 feet below the transmission line. The guard wires on the ends of the telephone cross-arms are located about 1 foot from the telephone wires and about 3 inches above them, and are carried one span on each side of the joint pole. These guard wires also are supported on high-potential insulators. The upper framework is so laid out that the outer guard wires come directly over the guard wires on the lower cross-arms, so that if any of the high-tension wires break they cannot come in contact with the lower wires, for even if the free end were long enough to ordinarily reach these wires it would, with this arrangement, strike against the guard wire and thus be kept a safe distance from the telephone line. The above rule would require guard wires below the lower wires in addition to those above them, which of course can be provided either by means of curved brackets bolted to the side of the lower cross-arm and designed to hold the insulators at the desired level, or an additional cross-arm could be provided below the others on which to support these lower guard wires. With the arrangement shown in the sketch this was not considered necessary to accomplish the desired results, and consequently it was omitted.

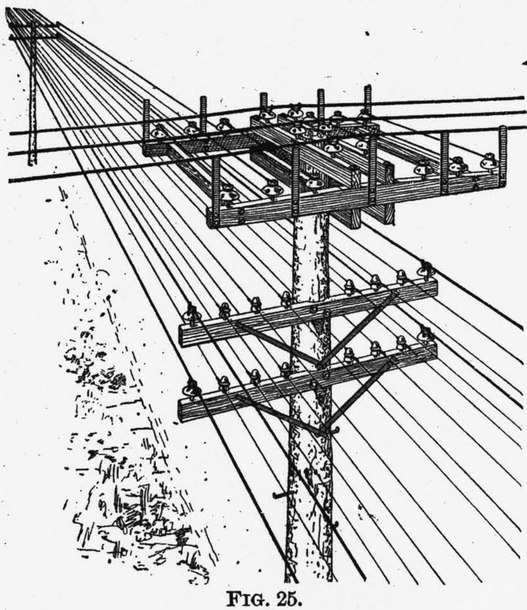


FIG. 25.
JOINT POLE CROSSING.

The end insulator guards extend about 6 inches above the level of

12 A. **Constant-Potential Pole Lines, over 5000 Volts** — *Continued.*

the transmission line and are intended to prevent a broken wire from getting over the side of the framework where it could fall on the wires beneath.

Where it is not desired to insulate the guard wires, as above described, they should be thoroughly grounded. The high-potential insulators would then not be needed, but the precautions given in the rule regarding size of wire, protection against destruction by arcing, excellent ground connection, etc., should be taken. It has been suggested that the entire joint-pole structure be made of steel and effectively grounded. Such a pole could undoubtedly be made stronger than the wooden pole and would probably last longer. All leakage currents from the high-tension line would be carried directly to earth, and in case of a broken high-pressure insulator or wire at this point the line would be definitely grounded and the transmission line probably shut down. There would seem to be practically no chance of sufficient arcing at the pole to destroy it and allow contact between the two lines. The all-metal structure would, therefore, appear preferable to the wooden pole, from the standpoint of the protection of the low-voltage circuits against high-pressure current. However, the danger to linemen working on the low-pressure wires on this pole would be increased and any fault in the insulation of the transmission line at this point would probably mean the immediate shutting down of the plant.

Which construction is best will depend on conditions, and the objections to all of them, outside of the difficulties which may arise from mutual ownership, may lead, in the majority of cases, to the use of the independent form of cross-over, previously mentioned, in preference to the joint pole.

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.

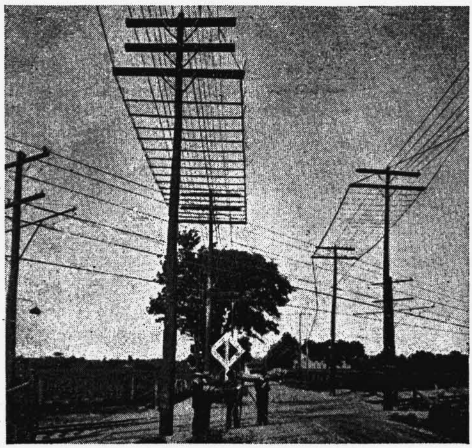


Fig. 26.
Crossing protected by Screen.

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 the screen will not be destroyed by any arcing at the point of contact likely to occur under the conditions existing.

This method of guarding against accidental contact of the high-tension line with other lines at point of crossing, by means of a screen of wires or "cradle" placed between them, is especially applicable where the high-pressure wires are below the others, for then there is little difficulty in sufficiently insulating the screen to take care of the telephone or low-volt-

12 A. **Constant-Potential Pole Lines, over 5000 Volts**— *Continued.*

age circuits, or if the screen is grounded there is less liability of destructive arcing when a broken wire falls onto the screen, except possibly where the broken circuit is of very large capacity.

Fig. 26 shows two screens installed under these conditions. Here several signaling circuits cross above an electric railway and transmission line. In this case the grill is made largely of wooden strips instead of wires, but the general results are the same for an insulated screen. The cross-strips are of maple, 1 inch by 2 inches by 12 feet, spaced 12 inches on centres. They are held at the ends by suspension wires fastened to the lower cross-arms. The poles are relieved of any undue strain by extending the suspension wires on both sides of the cross-over span and firmly anchoring them to the ground as shown in the case of the screen at the right of the cut. In order to prevent a broken wire sliding off of the screen at the sides, iron strips about ⅜ inch by ¾ inch are fastened to the ends of the wooden strips and project upwards.

If a grounded screen is desired it should probably be made entirely of wire instead of part wood as in the cut.

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

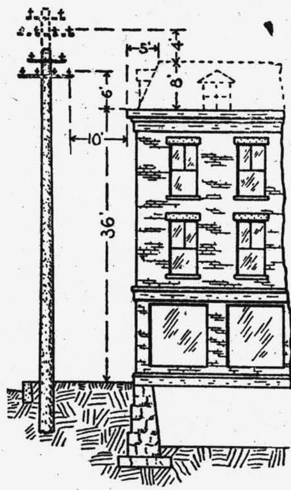


FIG. 27.

WIRES LOCATED WITH REFERENCE TO CORNICE.

In order to make the intent of the above rule and its application as clear as possible, the following example is given. Fig. 27 shows in full lines a three-story building with flat roof and simple cornice overhanging about 2 feet. The poles carrying the high-pressure wires are set just inside the curbing, say 15 feet from the building. The cross-arm is 6 feet long, bringing the outside wires say 3 feet each side of the pole. Therefore the wire nearest the building is 10 feet from the cornice, in horizontal projection. Reference to the above table will show that under these conditions the wires must be at least 6 feet above the cornice. If, now, the building had had a very steep pitched roof or especially one of the Mansard type, as shown in dotted lines in this sketch, it will be readily seen that the above arrangement would not be satisfactory, for the wires would be very liable to interfere with fighting fire in the roof. This is a similar condition to the one referred to in the first fine print note above. Assuming that the upper corner of the dotted roof is 5 feet back of the edge of the main cornice, this part of the roof is 15 feet from the nearest wire and consequently the wires must be raised 6 feet above their previous position in order that they may be 4 feet above the roof, as required in the above table when within 15 feet of the building, as in

12 A. **Constant-Potential Pole Lines, over 5000 Volts** — *Continued.*

this case. The cut shows very clearly to what extent the dotted Mansard roof affects the height of the pole.

13. Transformers.

(*For construction requirements, see Rule 62, page 117.*)

(*See also Rules 11, 13A and 36, pages 39, 52 and 84.*)

Where transformers are to be connected to high-voltage circuits, it is necessary 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.

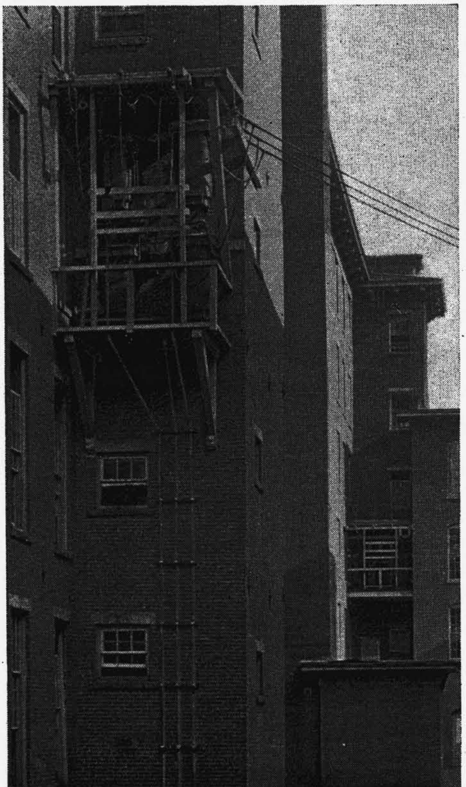


FIG. 28.

TRANSFORMERS ON PLATFORMS OUTSIDE OF BUILDINGS.

Where Factory Mutual mills are to take light or power from systems having a high primary voltage, the Inspection Department should always be consulted before work is begun or the apparatus purchased, so as to insure that only such apparatus is ordered as will meet the requirements of the case.

a. Must not be placed inside of any building, excepting central stations, unless by special permission of the Inspection Department having jurisdiction.

An outside location is always preferable, first, because it keeps the high-voltage primary wires entirely out of the building, and second, for the reasons given in the note to Rule 11 *a*, page 39.

It is very rarely necessary to locate transformers inside of buildings, especially in factory work, for there is generally plenty of available space on the outside walls. Wherever possible the transformers should be placed on a blank wall, and when this cannot be done, it is advised that the windows in the vicinity of them be made of wire glass, with tinned sashes. Under these conditions, a severe fire about the transformers would probably not seriously endanger the building before it could be extinguished.

The transformer station shown in the foreground of Fig. 28 consists of four transformers with a capacity of 25 K. W. each. The roof was found necessary, at this particular mill, to protect the apparatus from ice and snow falling from above, and the platform was provided for the

13. **Transformers** — *Continued.*

convenience and safety of the electrician in making repairs and changes. As a general rule, however, as little combustible material as possible should be used around the transformers. The three wires running down the wall are the ground wires from the three lightning arresters, which are mounted on the horizontal cross-bars in front of the transformers. These wires should usually be protected by heavy wooden boxing extending 7 or 8 feet above the ground and firmly secured to the wall. The ground connection at this plant is made with a copper plate, about as suggested on pages 30 and 31.

The station visible in the background of Fig. 28 is in every way similar to the one in the foreground.

Where it is impracticable or undesirable to locate transformers on the outside wall of a building, it may be feasible to place them in an underground vault just outside the foundation wall, as shown in Fig. 29. At this plant, the primary wires are brought to fuse boxes on the wall, and lead-covered cable is carried thence in iron pipe down into the vault. The cover is removable, and is made of wood tinned on both sides like a standard fire-door. Good ventilation is obtained by the two iron pipes shown at the ends, one pipe extending nearly to the bottom of the vault, and the other only just inside the top. The other requirements of Rule 36, page 84, have also been well carried out in this enclosure.

The secondary wires enter the building through iron pipes cemented into the wall, and the spaces between the wires and the pipes are filled up by cement, the wires being lead-covered.

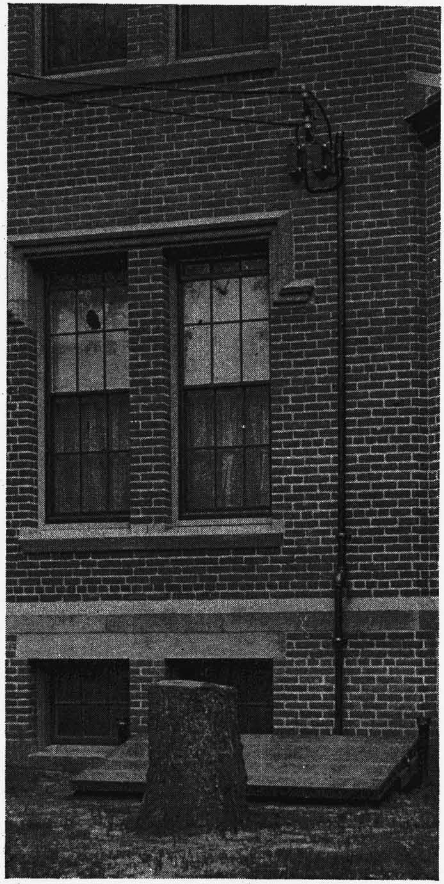


FIG. 29.

TRANSFORMER VAULT UNDERGROUND OUTSIDE OF BUILDING.

This is an excellent arrangement, as all high-voltage wires are kept out of the building and there is absolutely no opening between the vault and the building through which smoke or fire could pass.

FIG. 30.

TRANSFORMER ON OUTSIDE WALL.

Fig. 30 shows a single transformer bolted to two heavy wooden cleats on the outside wall of a brick building, and placed as far away as possible from the surrounding windows. This arrangement fulfills the requirements of § *b* with the least possible amount of combustible material,

13. **Transformers** — *Continued.*

and is heartily recommended. The two primary fuse boxes are located on the upper cleat, and the primary wires run nearly at right angles to the wall from a pole set well away from the building.

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

The intent of this rule is to provide an air-space between the transformer and the wall. If the transformer is in direct contact with the wall, a leakage current at this point might do considerable damage by electrolysis or charring before it was discovered. Two heavy wooden cross-bars, as shown in Fig. 30, page 51, are considered sufficient for this purpose.

13 A. 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 Three-Wire Systems.

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

1. Must be grounded at the central station on a metal plate buried in coke beneath permanent moisture level, and also through 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 §§ *c*, *e*, *f* and *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.

If the neutral is to be grounded at all, it should be done as thoroughly as possible, lest the current escape to the ground at points where the resistance is sufficient to cause unsafe heating.

A good ground connection may be made through any *main* water pipe that is thoroughly connected to underground pipes. The wire should be securely attached to the pipe by soldering it to a brass plug screwed into a fitting, or by binding it under a heavy split clamp, or by any other equally thorough method.

The methods of grounding advised for lightning arresters on pages 30 and 31 should, in general, be followed in grounding low-potential circuits.

Alternating-Current Secondary Systems.

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

1. The ground 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 between the grounded point and any other point in the circuit does not exceed 250 volts.

3. The ground connection must be at the transformer as

13 A. **Grounding Low-Potential Circuits** — *Continued.*

provided in §§ *d*, *e*, *f*, *g*, and when transformers feed systems with a neutral wire, the neutral wire must also be grounded at least every 250 feet for overhead systems, and every 500 feet for underground systems.

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

If the primary and secondary coils of a transformer come into contact electrically, the high-voltage primary current may flow to the secondary system. If this should happen, the life of any one handling any part of the secondary system would be endangered, and fires would probably be started by arcs caused by breaking down of the insulation of the wires or fittings on the secondary system. If, however, the secondary coil is grounded, a breakdown in the transformer cannot cause a dangerous difference of potential between the secondary system and the ground, and only with certain unusual combinations of contacts between the primary and secondary wires outside of the transformers will this protection fail to prevent the voltage of the secondary system from being raised above its normal limit. In order to secure the full benefit of the ground connection, reliable primary fuses of proper carrying capacity must be provided.

The *middle* of the secondary coil is the proper point to ground, as there is then only half the normal secondary voltage between either side and the ground, thus reducing the liability of a breakdown of insulation and also materially lessening the danger of fire if a breakdown does occur.

There is an objection to grounding the secondary on the other hand, for when this is done, the first breakdown of insulation may mean a short-circuit and a possible fire. With a system free from grounds, a breakdown must exist on each side of the system to cause a short-circuit, and with proper ground detectors the first can generally be discovered and remedied before the second occurs.

Grounding is therefore a choice of evils, but in many cases it is believed to be a lesser one than to risk getting the primary current on the secondary system. This is especially true where the primary voltage is high, say 3500 or over. For this reason it is advised that all transformers 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.

After the transformer secondary has been properly grounded a test should be made, especially if the transformer is some distance from the building supplied, in order to determine if the protection expected from the ground connection at the transformer is really effective inside the building in question, and if not the connection should be extended to accomplish the desired result. Cases have been known where the effectiveness of a ground connection has been limited to a comparatively small area, due to the exact conditions of the earth in the neighborhood of the ground plate and between it and the point where the protection due to the grounding was desired. The entire ground connection should be carefully examined at least once a year. (See page 31.)

Ground Connections.

c. The ground wire in direct-current three-wire systems must not at central stations be smaller than the neutral wire, and must not be smaller than No. 6 B. & S. gage elsewhere.

d. The ground wire in alternating-current systems must never be less than No. 6 B. & S. gage, and must always have a carrying capacity equal to that of the secondary lead of the transformer, or the combined leads where transformers are connected in parallel.

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

These requirements for the size of the ground wire are intended to

13 A. **Grounding Low-Potential Circuits** — *Continued.*

prevent the burning off of this connection, as well as to insure that it has sufficient mechanical strength to prevent its being easily broken. This end is accomplished by making the carrying capacity of the ground wire equal the combined capacities of all the wires for which, under any conditions, it may become the return wire.

e. The ground wire must be kept outside of buildings, but may be directly attached to the building or pole. The wire must be carried as nearly in a straight line as possible, and kinks, coils and sharp bends must be avoided.

Kinks, coils, etc., are objectionable, as they impede the flow of an alternating current or a lightning discharge.

f. The ground connection for central stations, transformer sub-stations and banks of transformers must be made through metal plates buried in coke below permanent moisture level, and connection should also be made to all available underground piping systems, including the lead sheaths of underground cables.

This method of grounding is fully described on pages 30 and 31.

g. For individual transformers and building services, the ground connection may be made as in § *f*, or may be made to water or other piping systems running into the 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., but connection must never be made to any lead pipes which form part of gas services.

In connecting a ground wire to a piping system, the wire should, if possible, be soldered into a brass plug and the plug forcibly screwed into a pipe-fitting, or, where the pipes are of 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 plugs cannot be used, the surface of the pipe may be filed or scraped bright, the wire wound around it, and a strong clamp put over the wire and firmly bolted together.

Where ground plates are used, a No. 16 Stubbs' gage copper plate, about 3 by 6 feet in size, with about 2 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 connections 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.

This method of grounding is illustrated on page 31.

In addition to connecting the ground wire to the street side of meters, etc., as above required, it should be connected to the piping on the other side of them also, in order to be sure that the protection is still effective in case these appliances should be removed.

Class C.

INSIDE WORK.

All Systems and Voltages.

GENERAL RULES.

14. **Wires.**

(*For special cases, see Rules 18, 24, 35, 38 and 39, pages 61, 69, 83 and 85.*)

a. Must not be smaller than No. 14 B. & S. gage, except as allowed under Rules 24 *v* and 45 *b* (pages 75 and 89).

It has been found by experience that wires smaller than the sizes specified are not mechanically strong enough to be safely used.

b. Tie wires must have an insulation equal to that of the conductors which they confine.

c. 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.

Stranded wires 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 connections.

All joints must be soldered, even if made with some form of patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these rules.

Connections by clamps, screws, etc., are not reliable where stranded wire is used. It is generally impossible to thoroughly connect all of the strands by such a method, and consequently the whole current has to be carried by a part of them, which is likely to result in their becoming dangerously hot.

See also note under Rule 12 *f*, page 41.

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 as provided in Rule 24 *u*, page 75.

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.

An insulating tube or bushing should be continuous, and of sufficient length to extend beyond the face of the wall at least ¾ inch. On the other hand, it should not extend so far out as to make it liable to be broken by the strain on the wire or by the ordinary brushing down of the rooms.

Broken bushings should not be used, as the sharp edges will injure the insulation. Even where attempts have been made to smooth these edges, the conditions have generally been improved but little, if any. The presence of broken tubes is considered as evidence of poor workmanship.

14. **Wires**— *Continued.*

With a very thick wall, a single tube of sufficient length may not be readily obtainable, in which case the arrangement shown in Fig. 31 can be used. The iron pipe furnishes a continuous waterproof tube, and the bushings serve to insulate the wire and provide a smooth passage for it.

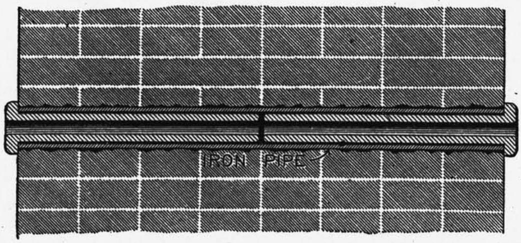


FIG. 31.
BUSHING FOR THICK WALL.

Where the wall is unusually thick, it is possible that two bushings would not be long enough to bush the entire length of the pipe. Under these conditions, the arrangement shown in Fig. 31 could still be used by inserting between the bushings a piece of lined conduit or flexible insulating tubing to protect the wire in this central space.

In all cases, the bushings should be firmly fastened in place, and the rough holes made in the wall for the tubes should be cemented up as soon as the latter are in place.

e. Must be kept free from contact with gas, water or other metallic piping, or any other conductors or conducting material which they may cross, by some continuous and firmly fixed non-conductor, creating a separation of at least 1 inch. Deviations from this rule may sometimes be allowed by special permission.

FIG. 32.
OVERHEAD WIRING, SHOWING USE OF STRAIN INSULATORS.

When one wire crosses another wire, the best and usual means of separating them is by means of a porcelain tube on one of them. The tube should be prevented from moving out of place, either by a cleat at each end, or by taping it securely to the wire.

The same method may be adopted where wires pass close to iron pipes, beams, etc., or, where the wires are above the pipes, as is generally the case, ample protection can frequently be secured by supporting the wires with a porcelain cleat placed as nearly above the pipe as possible.

Both of the methods described above are well illustrated in Fig. 33, which also shows the following additional good points :—

1. The mains from timber to timber are very tight and well sup-

14. **Wires** — *Continued.*

ported. By means of turn-buckles used with strain insulators, in the manner shown in Fig. 32, these wires may be kept taut.

2. Where the wires are wrapped around the timbers, the cleats on the ceiling are set off from the timbers about 3 or 4 inches, which is believed to be the best arrangement. Where this cleat is crowded into the corner, the vertical wires soon come in contact with the side of the timber, as a result of the inevitable slackening of the wires, caused by the shrinking of the wood as well as by the rough usage received in "sweeping down," which in many places has to be done very often. On the other hand, if the distance between the cleat and the timber is made much greater, say 12 or even 18 inches, as has sometimes been done, the wires are too much exposed to the knocks of brooms, ladders, etc., and soon become deranged. With this arrangement any slack wire can later be readily taken up by moving the cleats a little nearer the corner, without disturbing the rest of the wiring.

3. The wires are protected in iron pipe the entire distance from floor to ceiling.

4. There is a general order and neatness evident throughout, indicating careful planning and good workmanship.

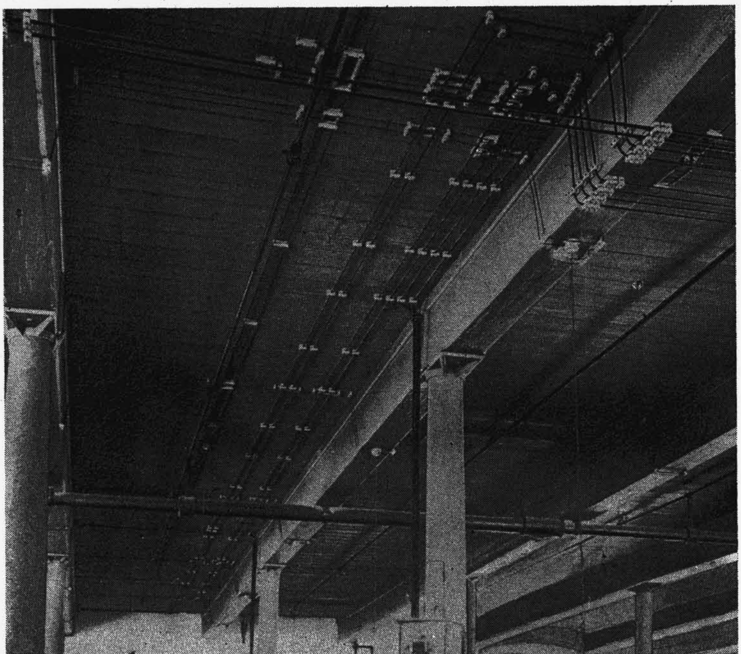


FIG. 33.
EXAMPLE OF GOOD OVERHEAD WIRING.

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.

If the wires are below the pipes, water may drip down upon them and run along to and over the insulators, thus forming between the wires and the building a connection which would be liable, in time, to cause a short-circuit or a dangerous ground.

15. **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.

There being often no safety fuses for such underground wires, a contact between wires, or between the wires and the ground, would result in serious arcing and perhaps in even melting off the wires.

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

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.

16. **Table of Carrying Capacity of Wires.**

a. The following table, showing the allowable carrying capacity of copper wires and cables of 98 % 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 84 % of that given in the following tables for copper wire with the same kind of insulation.

B. & S. Gage.	Table A. Rubber Insulation. See Rule 41. Amperes.	Table B. Other Insulations. See Rules 42 to 44. 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	200,000
300,000	270	400	300,000
400,000	330	500	400,000
500,000	390	590	500,000
600,000	450	680	600,000
700,000	500	760	700,000
800,000	550	840	800,000
900,000	600	920	900,000
1,000,000	650	1,000	1,000,000
1,100,000	690	1,080	1,100,000
1,200,000	730	1,150	1,200,000

16. **Table of Carrying Capacity of Wires** — *Continued.*

Circular Mills — *Con.*	Table A. Rubber Insulation. See Rule 41. Amperes.	Table B. Other Insulations. See Rules 42 to 44. Amperes.	Circular Mills.
1,300,000	770	1,220	1,300,000
1,400,000	810	1,290	1,400,000
1,500,000	850	1,360	1,500,000
1,600,000	890	1,430	1,600,000
1,700,000	930	1,490	1,700,000
1,800,000	970	1,550	1,800,000
1,900,000	1,010	1,610	1,900,000
2,000,000	1,050	1,670	2,000,000

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.

The carrying capacity for No. 16 and No. 18 B. & S. gage wire is given, but no smaller than No. 14 is to be used, except as allowed under Rules 24 *v* and 45 *b*, pages 75 and 89.

There is a general agreement among those familiar with the effect of heat on rubber, that, if long life is desired, the temperature should not exceed 150° F.

In 1889, Mr. A. E. Kennelly made an elaborate series of careful experiments at the Edison Laboratory, to determine the temperature rise caused in wires under different conditions by currents of various strengths.

The currents given in Table A are about 60 % of the currents which Mr. Kennelly found caused a rise of 75° F., or a final temperature of about 150° F., assuming 75° F. as the average indoor temperature. This margin of 40 % is to allow for inevitable increase of current, such as that produced by the changing from one size lamp to those of a larger candle-power, the adding of more lamps to a circuit, the overloading of a motor, etc. The currents given in Table A cause a rise of temperature of about 29° F. above the surroundings, but varying somewhat with the size of the wire. It is well to remember in this connection that the heating effect increases about as the square of the current, — *i. e.*, if the current is doubled, for instance, the heating effect increases four times.

The limiting temperature for weatherproof insulation is about the same as for rubber, but a smaller factor of safety is allowable, as the covering on this class of wire is not greatly depended on for insulation, the insulation of the system being secured by the porcelain or glass supports to which the wire is attached. The currents in Table B, therefore, were obtained by taking 90 % of the currents which Mr. Kennelly found caused the wire to reach a temperature of 150° F., when the surrounding air was at 75° F. This allows a margin of only 10 % instead of the 40 % considered necessary in Table A.

It is interesting to note that, for any given size of wire, a current about three times as great as that given in Table A causes all ordinary insulations to begin to smoke.

Owing to the cooling effect of air currents, the safe carrying capacity of outdoor conductors may be several times greater than the above, without causing any dangerous rise of temperature. As the conditions will vary so widely, and as such outdoor conductors are not at all liable to cause fire, no table has been made for them.

The following table shows, to the nearest .01 ampere, the current consumed by incandescent lamps of various candle-powers, at the voltages in most common use. This table is figured on the basis of an efficiency of 3.6 watts per candle-power for the 52, 104, and 110 volt lamps, and 4.0 watts per candle-power for the 220 volt lamps.

Voltage.	8 c. p.	10 c. p.	16 c. p.	20 c. p.	24 c. p.	32 c. p.	50 c. p.
52	.55	.69	1.11	1.38	1.66	2.22	3.46
104	.28	.35	.55	.69	.83	1.11	1.73
110	.26	.33	.52	.65	.78	1.05	1.64
220	.15	.18	.29	.36	.44	.58	.91

17. Switches, Cut-Outs, Circuit-Breakers, etc.

(*For construction requirements, see Rules 51, 52 and 53, pages 96, 101 and 104.*)

a. Must, unless otherwise provided (for exceptions see Rules 8 *c* and 22 *c*, pages 34 and 67), be so arranged that the cut-outs will protect, and the opening of the switches or circuit-breakers will disconnect, all of the wires; that is, in a two-wire system the two wires, and in a three-wire system the three wires, must be protected by the cut-out and disconnected by the operation of the switch or circuit-breaker.

It is much safer to have all wires of a circuit disconnected from the source of current when the safety devices operate or switches are open. Otherwise short-circuits might be made or shocks received on wires supposed to be dead, especially if the system is grounded.

b. Must not be placed in the immediate vicinity of easily ignitible material or where exposed to inflammable gases or dust or to combustible flyings.

In starch and candy factories, grain elevators, flouring mills and buildings used for wood-working or other purposes which would cause the fittings to be exposed to dust and flyings of inflammable material, the cut-outs and switches should be placed in *approved* cabinets outside of the dust-rooms. If, however, it is necessary to locate them in the dust-rooms, the cabinets must be dust-proof and must be provided with self-closing doors.

An arc is always formed when a switch is opened while carrying current, the intensity and duration depending on the strength of the current, the design and condition of the switch and the speed with which it is operated. Combustible dust, lint or flyings are liable to be ignited by such an arc, and hence the switch should be so located or enclosed that they cannot accumulate around it. Under certain conditions, it may be necessary to so arrange the switch that it can be operated from the outside, without having to open the enclosing cabinet, as shown in Fig. 13, page 33.

Air-break circuit-breakers and link fuses, if operated by a sudden heavy overload or a short-circuit on the system, make a considerable flash and often throw out hot melted metal, bits of hot carbon, etc., so that it is important to isolate them from all readily inflammable material.

c. Must, when exposed to dampness, be either enclosed in a waterproof cabinet or mounted on porcelain knobs.

For the reasons given in the note under Rule 3 *d*, page 28.

d. Time switches must be enclosed in an iron box or a cabinet lined with fire-resisting material.

If an iron box is used, the minimum thickness of the iron must be .128 inch (No. 8 B. & S. gage). If a cabinet is used it must be lined with marble or slate at least 1/8 inch thick or with iron not less than .128 inch thick. Box or cabinet must be so constructed that when the switch opens, the blades shall clear the door by at least 1 inch.

These switches, being automatic, are liable to fail, especially the cheaper grades, in which case severe arcing may result. The enclosing of the switches is therefore necessary in order to prevent as far as possible igniting surrounding combustible material, should such failure occur. The 1 inch clearance between the cabinet, when closed, and any moving part of the switch in any position is, first, to merely prevent the cabinet interfering with free movement of the entire mechanism; and second, to guard against short-circuit due to contact of live parts with the cabinet, in case it is made of iron or is iron lined.

CONSTANT-CURRENT SYSTEMS.

Principally Series Arc Lighting.

18. **Wires.**

(*See also Rules 14, 15 and 16, pages 55 and 58.*)

a. Must have an *approved* rubber insulating covering. (See Rule 41, page 86.)

The high voltages generally employed with these systems make it desirable to have the very best insulation.

b. Must be arranged to enter and leave the building through an *approved* double-contact service switch (see Rule 51 *b*, page 97), mounted in a non-combustible case, kept free from moisture and easy of access to police or firemen.

This is to make it possible to cut the high-voltage current entirely out of a building in case of fire. The switch is also necessary when work is to be done on the inside wires.

By "double-contact" switch is meant a switch which first short-circuits the loop which it controls, and then cuts it off, thus avoiding any break in the main circuit. In a constant-current system, the voltage at the terminals of the generator increases in direct proportion as the resistance of the circuit is increased, and the maximum is usually several thousand volts. If the circuit is broken at any point, this maximum voltage is available to maintain a very severe arc across the break, and this must be carefully guarded against, as such an arc is very destructive.

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

High voltage wires should always be located where they can be under constant inspection.

d. Must be supported on glass or porcelain insulators which separate the wire at least 1 inch from the surface wired over and must be kept *rigidly* at least 8 inches from each other, except within the structure of lamps, on hanger-boards, or in cut-out boxes or like places, where a smaller distance is necessary.

It is especially important with these high-voltage wires to secure perfect insulation of the system. Hence the required distance from the surface wired over and between the wires themselves is greater than that for low-voltage systems.

e. Must, on side walls, be protected from mechanical injury by a substantial boxing, retaining an air space of 1 inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than 7 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 ½ inch in thickness. Instead of the running-boards, guard strips on each side of and close to the wires will be accepted. These strips must be not less than ⅞ inch in thickness and at least as high as the insulators.

Except on joisted ceilings, a strip ½ inch thick is not considered sufficiently stiff and strong. For spans of say 8 or 10 feet, where there is but little vibration, 1 inch stock is generally sufficiently stiff; but where the span is longer than this or there is considerable vibration, still heavier stock should be used.

For general suggestions as to protecting wires on side walls, see notes under Rule 24 *e*, pages 70 to 72.

19. Series Arc Lamps.

(*For construction requirements, see Rule 57, page 114.*)

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.

"Open arc" lamps are always liable to throw off sparks, hot bits of carbon or even the entire red-hot carbon itself. The globe is intended to prevent the escape of such hot particles and to shield the arc from air drafts, knocks, etc.

With "enclosed arc" lamps, a tight globe about the arc is always provided, as this is necessary for the proper operation of the lamp.

c. Must be provided with a wire netting (having a mesh not exceeding 1¼ inches) around the globe, and an *approved* spark arrester (see Rule 58, page 114), when readily inflammable material is in the vicinity of the lamps, to prevent the escape of sparks of carbon or melted copper. It is recommended that plain carbons, not copper-plated, be used for lamps in such places.

Outside arc lamps must be suspended at least 8 feet 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, should 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 §§ *b* and *c* above would, of course, not apply to them, except that a wire netting around the inner globe may in some cases be required if the outer globe is omitted.

In Factory Mutual risks, the wire netting around the inner globe will be required if the outer globe is omitted and the lamp is located in the vicinity of combustible material.

The objection to copper-plated carbons in "open arc" lamps is that as the carbons burn away, the copper, not being consumed, collects in melted globules, which fall from time to time and are likely to cause a fire.

d. Where hanger-boards (see Rule 56, page 114) are not used, lamps must be hung from insulating supports other than their conductors.

The weight of the lamp, especially where the floors are subject to vibration, is liable to loosen the connections between the lamp and the conductors if they are used for supports. This would result in more or less arcing at the loose connection, which might in time melt off the wire and thus cause a break in the circuit. The serious consequences of such a break in a constant-current circuit are briefly referred to in the note to Rule 18 *b*, page 61.

In order to still further lessen the chances of loose connections, it is advised that the wires be soldered into all binding posts, etc., also that, as far as practicable, the leads to the lamps be stranded instead of solid, in order to minimize the chance of breakage of these conductors due to swinging of lamp or other vibrations.

20. Incandescent Lamps in Series Circuits.

a. Must have the conductors installed as required in Rule 18, page 61, and each lamp must be provided with an automatic cut-out.

The object of such cut-out is to automatically shunt the current around the lamp in case the circuit becomes broken, due to lamp jarring loose, lamp filament breaking, etc.; otherwise a destructive arc might be drawn under these conditions. (See note under Rule 18 *b*, page 61.)

20. **Incandescent Lamps in Series Circuits** — *Continued.*

b. Must have each lamp suspended from a hanger-board by means of a rigid tube.

This form of construction removes all strain from the binding screws which hold the wire in place in the socket, besides preventing the wires from coming into contact with surrounding objects, or from being broken by the constant handling and bending to which the ordinary cord pendant is subjected.

The voltage across a break anywhere in a series system is sure to be very high and to cause severe arcing, as explained in the note to Rule 18 *b*, page 61, and unusual precautions are therefore necessary.

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

Experience has shown that magnetic devices become rusty or filled with dust, and often fail when wanted.

Both multiple-series and series-multiple systems of lighting were once used, but gave a good deal of trouble and proved themselves generally unreliable.

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

It would be especially dangerous to attach these high-voltage wires to metal pipes so thoroughly connected with the ground, especially as an arc at this point might perforate the pipe and ignite the gas.

CONSTANT-POTENTIAL SYSTEMS.

GENERAL RULES—ALL VOLTAGES.

21. **Automatic Cut-Outs.** — *Fuses and circuit-breakers.*

(*For construction requirements, see Rules 52 and 53, pages 101 and 104.*)
(*See also Rule 17, page 60.*)

Excepting on main switchboards, or where otherwise subject to expert supervision, circuit-breakers will not be accepted unless fuses are also provided.

a. Must be placed on all service wires, either overhead or underground, as near as possible 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 Rule 22, page 65, is inside the building, the cut-out required by this section must be placed so as to protect it.

In risks having private plants, the yard wires running from building to building are not generally 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 purpose of such cut-outs is to make sure that the wires inside a building cannot be subjected to a current larger than they can safely carry. They are absolutely necessary when taking current from a public plant, as the fuses in the mains are often changed without regard to the size of the wires in the buildings.

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 Rule 16, page 58.)

It will frequently be found necessary to provide cut-outs where taps are taken from large mains. In such cases, if the clamps on the cut-outs are not sufficiently large and strong to give a firm and secure connection, a short length of smaller wire may be soldered to the main wire and then

21. **Automatic Cut-Outs** — *Continued.*

carried direct to the cut-out, which should be located as near as possible to the point of connection with the mains. Special care should be taken to guard these leads from accident as they may not be properly protected by the fuses in the main circuit.

c. Must be in plain sight, or enclosed in an *approved* cabinet (see Rule 54, page 108), and readily accessible. They must not be placed in the canopies or shells of fixtures.

The ordinary porcelain link-fuse cut-outs will not be approved. Link fuses may be used only when mounted on slate or marble bases, conforming to the requirements of Rule 52, page 101, and must be enclosed in dust-tight fireproofed cabinets, except on switchboards located well away from combustible material, as in the ordinary engine and dynamo room, and where these conditions will be maintained. It is, however, strongly recommended that enclosed fuses be used in all cases on panel boards or where cabinets are provided.

In such places as picker and carding rooms, cloth napping and shearing rooms, wood-working shops, etc., where inflammable dust or flyings are liable to accumulate about the fuses, cabinets should be provided in all cases, even with fuses of the enclosed type. See cuts and notes on pages 108 to 110 for illustrations and description of good cabinets.

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, stage borders, and illuminated signs.

The above rule shall also apply to motors when more than one is dependent on a single cut-out.

The idea is to have a small fuse to protect the lamp socket and the small wire used for fixtures, pendants, etc. It also lessens the chances of extinguishing a large number of lights if a short-circuit occurs.

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 rosette not to exceed 2 amperes; a fuse of over 25 amperes must not be used in the branch circuit.

All branches or "taps" from a three-wire Edison system must be run as two-wire circuits.

Incandescent lamps in series on constant potential systems will not be approved in Factory Mutual mills. Sockets, flexible cord and rosettes are not suitable for over 250 or 300 volts, so that under no condition would it be proper to use these fittings on circuits of higher voltage than this. Such a series system should consequently be limited to 250 volt circuits for which single lamps can be procured. Therefore, where a 250 volt system is required for any reason, 250 volt lamps should be used, or the lighting circuits run as an Edison three-wire system, using 125 volt lamps. The frequent inconvenience or poor economy of the series arrangement should also be considered. Where higher voltage circuits are necessary, say 500 volts, lamps could still be connected by means of the Edison three-wire system using 250 volt lamps. (See also Rule 24*a*, page 69.) This higher voltage, especially with direct current, should be avoided wherever practicable.

The average incandescent lamp consumes about 3½ watts per candle-power, so that 12 lamps of 16 c. p. each or 6 lamps of 32 c. p. each would consume about 660 watts.

Unless fused rosettes are used, the fuses in the branch cut-outs should not have a rated capacity greater than 6 amperes on 110 volt systems, and 3 amperes on 220 volt systems.

If ceiling rosettes are used,—either fused or fuseless,—there must be a separate one for each pendant and they must be supported independently of the overhead wires.

21. **Automatic Cut-Outs** — *Continued.*

e. The rated capacity of fuses must not exceed the allowable carrying capacity of the wire as given in Rule 16, page 58. Circuit-breakers must not be set more than 30 % above the allowable carrying capacity of the wire unless a fusible cut-out is also installed in the circuit.

Specifications for fuses require that they shall be rated at a certain per cent of the maximum current which they will carry indefinitely, as follows : link fuses 80 % and enclosed fuses 90 %. The margin thus provided between the rating of the fuse and its actual melting point will permit the ordinary fluctuations in current without opening the circuit. If fuses selected to conform to the above rule are not large enough to carry the load, it is evident that the wires also are overloaded, and either the load should be diminished or the size of the wire increased.

Circuit-breakers are so sensitive that it is often necessary to set them much above the ordinary current to keep them from being constantly opened by momentary rises in the current, such as might be caused by starting a motor or by a rise in the voltage of the dynamo due to a sudden decrease of load. When this is the case, a fuse may be necessary to protect the wire from a steady current above the safe carrying capacity of the wire but below the point at which the circuit-breaker is set to open. The fuse requires a little time to heat, and so does not melt with the momentary rises of current which would open the circuit-breaker if it were set as low as it would have to be if the fuses were not provided.

22. Switches.

(For construction requirements, see Rule 51, page 96.)
(See also Rule 17, page 60.)

a. Must be placed on all service wires, either overhead or underground, in a readily accessible place, as near as possible 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 generally considered as service wires, so that switches will not be required in each building if there are other switches conveniently located on the mains or if the generators are near at hand.

The purpose of such switches is to make sure that current can be cut off from the inside wires for repairs, or in case of fire or other accident. They are, of course, absolutely necessary when taking current from public lines.

If there are any high-voltage wires in the mill yard, especially in the vicinity of the buildings, it might be necessary to shut off the current from these wires before any effective fire fighting could be done, in which case some means should be available for instantly disconnecting these wires from the source of power. If the power station is close at hand, arrangements could probably be made to have the circuit opened there at a moment's notice. Otherwise, an emergency switch should always be installed in each of these high-voltage wires at the point where they enter the mill yard.

An excellent arrangement for such a switch, where a switch house as shown in Fig. 3, page 4, is not feasible, is illustrated in Fig. 34, page 66. The cut shows two high-tension circuits carried into the mill yard, an oil switch or circuit-breaker being provided in each circuit and located on a pole at the yard line. These emergency switches are properly housed to protect them from the weather. In this case, the switches are tripped electrically by means of an auxiliary circuit. Just below each switch cabinet will be seen a small transformer, the primaries being connected through fuse boxes to the high-tension circuit on the mill side of the emergency switch. The 110 volt secondary circuit is carried to the tripping mechanism at the

22. **Switches** — *Continued.*

switch, and thence into the mill to small single-pole knife switches connected in parallel and located at different points from which it is desired to operate the emergency switch. By closing any of the small switches, the main switch may be instantly opened.

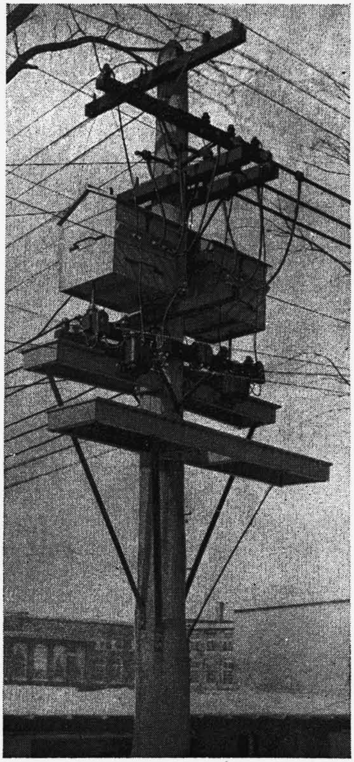


FIG. 34.
EMERGENCY SWITCHES ON POLE.

At each of the controlling switches is located a red lamp, connected in parallel with the switch, which gives a conspicuous and continuous indication of the condition of the secondary or controlling circuit. If the lamp burns, it is evident that the circuit is intact and that current is available for throwing the main switch. The lamps, switches, and tripping coil are so connected that the closing of any of the small controlling switches will not extinguish the lamps unless the emergency switch has opened. The lamp is, therefore, a valuable tell-tale regarding both the maintenance and operation of what may be called the remote control. Where oil circuit-breakers are used in this way, care should be taken that the oil does not become sufficiently thick, even in extreme cold weather, to interfere with the prompt operation of the breaker or tripping mechanism.

The great advantage of the remote control is the saving of time in case of fire or other accident, for as many controlling switches may be provided at different points as may be considered necessary to make the control readily accessible under all conditions. For example, one switch could be placed upon the main distributing switchboard, within easy reach of the switchboard attendant; another could be located just outside of the building, so that it could be closed at a moment's notice, even in case of fire in the building, etc. The auxiliary circuit should be tested at least once a week by actually opening the emergency switches, if conditions will permit.

It is possible, however, that even with the best of care this circuit might be found disabled when needed, and therefore some means of direct control of these switches is believed also desirable for most reliable service. Such direct control could be secured by attaching a rope to the tripping device of the circuit-breaker or to the handle of a plain switch, as the case may be, and carrying this rope to within easy reach of the ground, the arrangement being such that the circuit could be safely and quickly opened, without its becoming necessary to climb the pole, which might be an extremely dangerous undertaking. To protect the rope from the weather and guard against tampering with the electrical circuit, this rope could be run in suitable boxing on the side of the pole, a door being provided at the bottom which could ordinarily be kept locked, but which should be so made that it could be readily broken open in case of emergency. Where space is limited in the vicinity of the switch, a length of iron conduit could be fastened firmly to the pole and extended through the bottom of the switch cabinet. Enameled pipe should be used, thus securing a very smooth runway for the rope. The pipe should enter the wooden boxing a good distance from the ground, say half-way up the pole, so that if the pipe should accidentally become "alive," it would not endanger people passing near the pole.

For most cases a suitable high-voltage switch is considered advisable for this use, as then the high-tension current can readily be cut out of

22. **Switches** — *Continued.*

the mill yard whenever the electric plant is shut down. However, with lines of small capacity and of comparatively low voltage, say 2000, where the conditions are favorable, a somewhat cheaper arrangement in the form of a substantial 500 volt single-pole switch in each wire might be used and operated by a rope as above described.

Whenever it is proposed to introduce high-voltage current into Factory Mutual mills, the Inspection Department should first be consulted, so that all of these questions, such as location of line, style of emergency switch, lightning protection, etc., can be fully considered and the best arrangement determined before the work is begun.

b. Must always be placed in dry, accessible places, and should be grouped as far as possible. Knife switches must be so placed that gravity will tend to open rather than to close them.

When possible, switches should be so wired that blades will be "dead" when switch is open.

If knife switches are used in rooms where combustible flyings would be likely to accumulate around them, they should be enclosed in dust-tight cabinets. (See note under Rule 17 *b*, page 60.) Even in rooms where there are no combustible materials it is better to put all knife switches in cabinets, in order to lessen the danger of accidental short circuits being made across their exposed metal parts by careless workmen.

Up to 250 volts and 30 amperes, *approved* indicating snap switches are advised in preference to knife switches on lighting circuits about the workrooms.

It is not desirable to have switches scattered about at random, and it is easier and cheaper to install and care for them properly if grouped.

If knife switches are not placed so that gravity tends to open them, weakening or breaking of the spring may allow them to partly close, causing arcs and burning.

Specifications and cuts of good cabinets are given on pages 108 to 110.

c. Must not be single-pole when the circuits which they control supply devices which require over 660 watts of energy, or when the difference of potential is over 300 volts.

See notes under Rule 17 *a* and 21 *d*, pages 60 and 64.

d. Where flush switches are used, whether with conduit systems or not, they must be enclosed in *approved* switch boxes. (See Rule 49 A, page 94.) 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.

This requires an *approved* box in addition to the porcelain enclosure of the switch.

e. Where possible, at all switch or fixture outlets, a ⅞ inch block must be fastened between studs or floor timbers, flush with the back of lathing, to hold tubes and to support switches or fixtures. When this cannot be done, wooden base blocks not less than ¾ 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 tubing.

23. **Electric Heaters.**

a. Must, if stationary, be placed in a safe situation, isolated from inflammable materials, and must be treated as sources of heat.

23. Electric Heaters— *Continued.*

Electric heaters should not be located in dusty or linty places, and practically the same precautions should be taken as required for resistance boxes (see Rule 4 *a*, page 28), especially for stationary heaters, unless the heaters are so designed that these precautions are unnecessary for desired safety.

b. Must each have a cut-out and an *indicating* switch. (See Rule 17 *a*, page 60).

c. The attachments of feed wires to the heaters must be in plain sight, easily accessible, and protected from interference, accidental or otherwise.

d. The flexible conductors for portable apparatus, such as irons, etc., must have an *approved* insulating covering. (See Rule 45 *g*, page 90.)

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

Stationary heaters should be treated like stoves which might become overheated at any time.

Portable heaters, such as flat-irons, have this danger, that if left standing with the current on they in time accumulate heat enough to char combustible material and to finally set it on fire.

It is often desirable to connect in multiple with the heaters, 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.

Special care should be taken in arranging circuits for portable heaters to have switches so located that any department not in operation can have the current cut entirely out of it. Current should of course be cut off from all lines at night when work stops. The pilot lamp above mentioned should be so connected to the heater circuits that it would be necessary to open the main switch in order to put out this light. A red pilot lamp would make the indication even more conspicuous, and thus emphasize the fact that current was on these circuits in case the switch, for any reason, had been left closed.

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 10 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 10 volts or less. The potential difference on the primary circuit must not exceed 3500 volts.

(For 550 volt motor equipments a margin of 10% above the 550 volt limit will be allowed at the generator or transformer.)

Before pressure is raised above 300 volts on any previously existing system of wiring, the whole must be strictly brought up to all of the requirements of the rules at date.

24. **Wires.**

General Rules.

(*See also Rules 14, 15 and 16, pages 55 and 58.*)

a. **Must be so arranged that under no circumstances will there be a difference of potential of over 300 volts between any bare metal parts in any distributing switch or cut-out cabinet or equivalent centre of distribution.**

This rule is not intended to prohibit the placing of switches or single pole cut-outs for motor systems of voltages above 300 in cabinets, but would require that the cabinets be divided by approved barriers so arranged that no single section shall contain more than one switch nor more than one single pole cut-out.

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

Fresh plaster and cements may be either alkaline or acid, and until finally set have a corrosive action on the insulating materials of the wires. The amount of such alkaline or acid action is not only often sufficient to destroy the insulation, but will sometimes even injure the wire itself.

A staple driven over a wire will almost always cut through the insulation or even crack the wire itself, and this may result in an arc which would develop heat enough to set fire to the insulation.

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.

It is desirable to do as little fishing as possible, as the condition of the fished wires is always somewhat uncertain.

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

A twin wire is made up by placing two separately insulated wires under the same insulating covering. It is unsafe for light or power work on account of the short distance between the two conductors, and the readiness with which an arc starting at one end will follow along the wire.

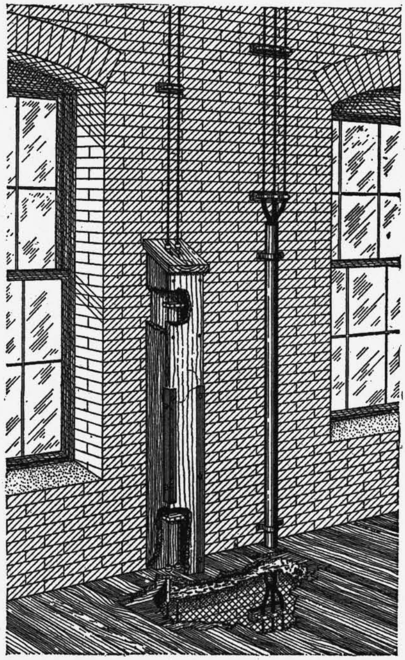


Fig. 35.
Protection for Wires on Side Walls.

Twin wire may be used in conduit work with reasonable safety, however, since the liability of mechanical injury to the wire is there so small that the chance of starting an arc between them is greatly reduced. Moreover, the conduit gives some added protection to the surroundings against the heat of an arc, in case one should occur.

e. Must be protected on side walls from mechanical injury. When crossing floor timbers in cellars, or in rooms where they might be exposed to injury, wires must be attached by their

24. **Wires** —*Continued.*

insulating supports to the under side of a wooden strip not less than ½ inch in thickness and not less than 3 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 ⅞ inch in thickness, and at least as high as the insulators.

Suitable protection on side walls may be secured by a substantial boxing, retaining an air space of at least 1 inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than 5 feet from the floor; or by an iron-armored or metal-sheathed insulating conduit sufficiently strong to withstand the strain to which it will be subjected, and with the ends protected by the lining or by special insulating bushings, so as to prevent the possibility of cutting the wire insulation; or by plain metal pipe, lined with *approved* flexible tubing, which must extend from the insulator next below the pipe to the one next above it.

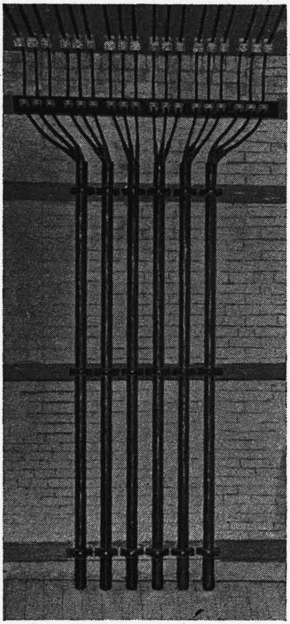


FIG. 36.
IRON PIPE PROTECTION, SHOWING SEPARATION OF WIRES ABOVE PIPES.

If metal conduits or iron pipes are used to protect wires carrying alternating currents, the two or more wires of each circuit *must* be placed in the same conduit, as troublesome induction effects and heating of the pipe might otherwise result; and 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. This should also be done in direct-current wiring if there is any possibility of alternating current ever being used on the system.

For high-voltage work, or 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 these exceptions, however, iron pipe 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.

Fig. 35, page 69, shows both the wooden boxing and metal pipe protection. In the cut the boxing has been broken away to show the backing board on which the insulators should be mounted. This board should first be fastened to the wall, and the boxing then built around the wires as outlined in the above note. Good heavy stock should be used, as these boxes are generally subjected to considerable hard usage. Where the boxing is especially liable to knocks from trucks and the like, heavy angle irons should be securely fastened to the corners as shown. The floor bushings should have long heads, to surely prevent wash water reaching the wires, and the bushings in the top should be short, say 1½ inches, to prevent breaking. A considerable slant should be given the top to prevent its use as a shelf, and to better shed dust, etc.

If there is any liability of storage or other materials being piled in the vicinity of these wires, the protecting boxing or piping should be carried higher than 5 feet, so as to surely guard the wires from injury.

Although the cut illustrates a three-wire system protected by the flexible tubing and iron pipe, the method is, of course, entirely applicable to any system. This arrangement is excellent for several reasons:—

1. It takes but little room, and is therefore much less in the way than the wooden boxing.

2. It is mechanically very strong, giving ample protection to the wire against hard knocks, etc.

3. It provides an excellent floor bushing, which is readily made and is not easily broken.

24. **Wires** — *Continued.*

4. The amount of combustible material at this point is considerably reduced.

Where approved line conduit with single-braid rubber-covered wire, or unlined conduit with double-braid rubber-covered wire, is used in place of plain iron pipe, the reinforcing insulating tubing will not be required, but approved outlet bushings must be provided at each end of the conduit.

The plain iron pipe construction shown in Fig. 35, page 69, has been used in a large number of places with perfectly satisfactory re-

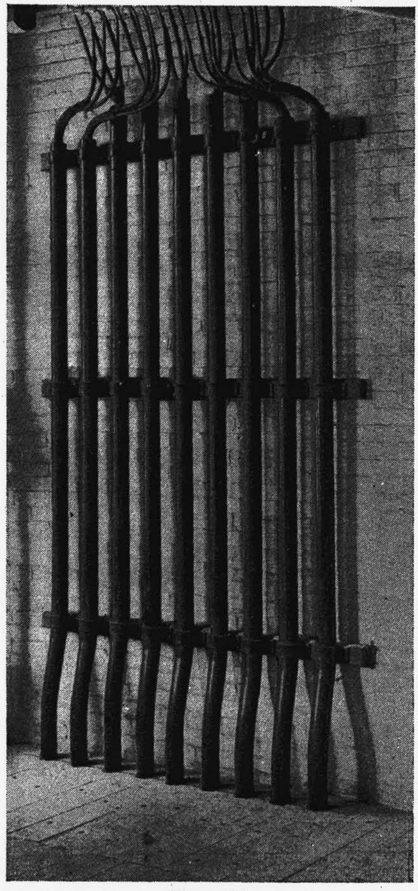


FIG. 37.

IRON PIPE PROTECTION, SHOWING PIPES BENT FOR OFFSET IN WALL.

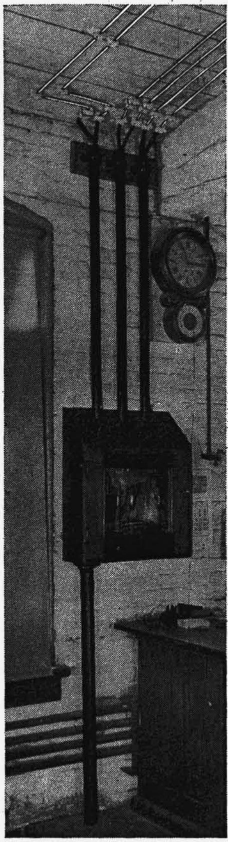


FIG. 38.

CABINET WIRING PROTECTED BY IRON PIPE.

sults. Figs. 36 and 37 illustrate some of the applications of this arrangement in practice, on low-voltage circuits. (See also Figs. 43 and 44, page 109.) In all of these cases, attention is called to the very substantial manner in which the pipes are secured in place and to the small amount of combustible material necessary with this type of construction. Fig. 37 shows how well this method can be used where offsets occur in the wall. In this cut the circuits in the five centre pipes are carried up near the wall, while the other circuits are brought forward and then pass directly up to cleats overhead. This arrangement gives ample separation between the wires, although it is not very evident in the cut. Fig. 38 shows an

24. **Wires** — *Continued.*

excellent application of iron pipe protection for wires entering and leaving a switch cabinet.

See also note under Rule 18 *e*, page 61.

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

Roofs and tanks are liable to leak, and moisture is sure to condense on cold pipes.

Special Rules.

For Open Work.

In Dry Places:—

g. Must have an *approved* rubber or "slow-burning weatherproof" insulation. (See Rules 41 and 42, pages 86 and 88.)

A "slow-burning weatherproof" covering 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.

This "slow-burning weatherproof" wire has special merit in linty and dusty places, for flyings will not readily adhere to the hard, smooth, dry outer surface, as is the case where the weatherproof braid is on the outside. The result is that the "sweeping down" process is much less severe on the wiring, which can therefore be kept in better condition. Another good point is that fire will not run rapidly along the wires, even when grouped. (See note to Rule 2 *b*, page 25.) The wire can also be more readily drawn into flexible tubing where the iron pipe described in § *e* is used.

"Slow-burning" wire also has the above advantages, and in Factory Mutual work *special permission in writing* will be given for using it where, on account of excessive heat or for other special reasons, this type of wire is preferable.

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
301 to 550	1 "	4 "

Rigid supporting requires, under ordinary conditions, where wiring along flat surfaces, supports at least every 4½ feet. If the wires are liable to be disturbed, the distance between supports should be shortened. In buildings of mill construction, mains of No. 8 B. & S. gage wire or over, where not liable to be disturbed, may be separated about 6 inches and run from timber to timber, not breaking around, and may be supported at each timber only.

This rule will not be interpreted to forbid the placing of the neutral of an Edison three-wire system in the centre 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 2½ inches.

The proper distance between insulators depends largely on the surroundings. In places where ceilings are low, or where belts, shafting or other machinery may require frequent attention, insulators should be placed every few feet, in order to prevent the wires from being displaced by careless or unavoidable blows from workmen. On the other hand, with a high ceiling and no chance of derangement, a greater distance would be allowable.

The whole idea is to so rigidly secure the wires that they cannot come in contact with each other or any other conductors, if loosened by shrinkage of timbers and floors or by careless knocking.

Wires should not be "dead-ended" at rosettes, but should always be

24. **Wires** —*Continued.*

carried beyond them for a few inches and securely fastened with porcelain cleats.

See Fig. 33, page 57, for illustration of good wiring for buildings of mill construction.

In damp places or buildings especially 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. (See Rules 41 and 44, pages 86 and 89.)

j. Must be rigidly supported on non-combustible, non-absorptive insulators which will separate the wire at least 1 inch from the surface wired over, and must be kept apart at least 2½ inches for voltages up to 300, and 4 inches for higher voltages.

Rigid supporting requires, under ordinary conditions, where wiring over flat surfaces, supports at least every 4½ feet. If the wires are liable to be disturbed, the distance between supports should be shortened. In buildings of mill construction, mains of No. 8 B. & S. gage wire or over, where not liable to be disturbed, may be separated about 6 inches and run from timber to timber, not breaking around, and may be supported at each timber only.

k. (Stricken out.)

For Moulding Work.

l. Must have an *approved* rubber insulating covering. (See Rule 41, page 86.)

The absence of the porcelain insulators required for open work, and the close proximity into which the wires are brought, makes it necessary to have the best of insulation on them.

m. Must never be placed in moulding in concealed or damp places, or where the difference of potential between any two wires in the same moulding is over 300 volts.

As a rule, moulding should not be placed directly against a brick wall, as the wall is likely to "sweat" and thus introduce moisture back of the moulding.

If water should soak into the wood, it might cause leakage of current between the wires, charring the wood and starting a fire which would not be immediately discovered.

It is to be understood that the sole object of the moulding is to furnish a convenient and fairly good-looking runway, in which the wires are protected from mechanical injury. Nails used for fastening on the capping must be very carefully driven, so as to avoid injuring the insulation, and must never be used to hold the wires in the grooves.

For Conduit Work.

n. Must have an *approved* rubber insulating covering. (See Rule 47, page 91.)

Here, too, the conductors need the best of insulating covering, as there is no other separation between them.

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

24. **Wires**— *Continued.*

This makes it absolutely necessary that the conduit should be complete from one junction box to another, and that all joints be carefully made. If wires were laid in the conduits while the latter were being installed, it would be very easy to neglect these points.

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

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

The same conduit must never contain circuits of different systems, but may contain two or more circuits of the same system.

With alternating-current systems, if the wires of the same circuit are in different iron conduits, there will be trouble from inductive losses, and under certain conditions the conduits may become dangerously heated. This trouble disappears if the two or more wires of the same circuit are drawn into the same conduit. The placing of two or more circuits in the same conduit should be avoided as far as possible.

For Concealed Knob and Tube Work.

q. Must have an *approved* rubber insulating covering. (See Rule 41, page 86.)

In concealed work, the condition of the wire is often unknown, so that the best insulation is necessary for safety.

r. Must be rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least 1 inch from the surface wired over. Must be kept at least 10 inches apart, and, when possible, should be run singly on separate timbers or studdings. 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.

Rigid supporting requires, under ordinary conditions, where wiring along flat surfaces, supports at least every 4½ feet. If the wires are liable to be disturbed, the distance between supports should be shortened.

It is believed that the use of a few extra knobs or cleats and a generous supply of tubes is advisable in such places, where the circuits are entirely concealed and any derangement of them could not, therefore, be seen.

s. When, in a concealed knob and tube system, it is impracticable to place any circuit on non-combustible supports of glass or porcelain, *approved* metal conduit, or *approved* armored cable must be used (see § *t*), 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 on the loop system if separately encased throughout in continuous lengths of *approved* flexible tubing.

There can, of course, be no assurance that such fished wires do not lie in close contact with gas or water pipes, or other wires, and so there is need of the protecting conduit.

t. Mixed concealed knob and tube work, as provided for in § *s*, must comply with the requirements of §§ *n* to *p*, and Rule

24. **Wires** — *Continued.*

25, page 76, when conduit is used, and with the requirements of Rule 24 A, when armored cable is used.

u. Must at all outlets, except where conduit is used, be protected by *approved* flexible insulating tubing, extending in continuous lengths from the last porcelain support to at least 1 inch beyond the outlet. In the case of combination fixtures, the tubes must extend at least flush with outer end of gas cap.

For Fixture Work.

v. Must have an *approved* rubber insulating covering (see Rule 46, page 91), and must not be smaller than No. 18 B. & S. gage.

The wire covering lies in contact with the metal of the fixtures, so that a first-class insulator, like rubber, is necessary.

It is very undesirable to use wires as small as No. 18, as they have but little mechanical strength and are easily broken by vibration of the fixture. They are only to be used in places where it is absolutely impossible to put a larger wire. Stranded wires are preferable to solid wires, as they are much less likely to break.

w. Supply conductors, and especially the splices to fixture wires, must be kept clear of the grounded part of gas pipes, and where shells or outlet-boxes are used, they must be made sufficiently large to allow the fulfilment 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. Under no circumstances must there be a difference of potential of more than 300 volts between wires contained in or attached to the same fixture.

24 A. Armored Cables.

(*For construction requirements, see Rule 48, page 92.*)

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.

In case of underground 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. (See Rule 54, page 108.)

b. Must be equipped at every outlet with an approved outlet box or plate, as required in conduit work. (See Rule 49 A, page 94.)

Outlet plates must not be used where it is practicable to install outlet boxes.

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 armored cable is firmly and rigidly secured in place.

c. Must have the metal armor of the cable permanently and effectively grounded.

24 A. **Armored Cables** — *Continued.*

It is essential that the metal armor of such systems be joined so as to afford electrical conductivity sufficient to allow the largest fuse or circuit-breaker in the circuit to operate before a dangerous rise in temperature in the system can occur. Armor of cables and gas pipes must be securely fastened in metal outlet boxes so as to secure good electrical connection. Where boxes used for centres of distribution do not afford good electrical connection, the armor of the cables must be joined around them by suitable bond wires. Where sections of armored cable are installed without being fastened to the metal structure of buildings or grounded metal piping, they must be bonded together and joined to a permanent and efficient ground connection.

d. When installed in so-called fireproof buildings in course of construction, or afterwards if concealed, or where it is exposed to the weather, or in damp places such as breweries, stables, etc., the cable must have a lead covering at least 1/32 inch in thickness placed between the outer braid of the conductors and the steel armor.

e. Where entering junction boxes and at all other outlets, etc., must be provided with *approved* terminal fittings which will protect the insulation of the conductors from abrasion, unless such junction or outlet boxes are especially designed and approved for use with the cable.

f. Junction boxes must always be installed in such a manner as to be accessible.

g. For alternating-current systems, must have the two or more conductors of the cable enclosed in one metal armor.

This is necessary in order to avoid heating of armor and other troubles due to induction, which might occur if each conductor were separately encased. See also notes under Rule 24 *g*, page 72.

25. Interior Conduits.

(*See also Rules 24 n to 24 p, and 49, pages 73 to 74 and 49.*)

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.

a. No conduit tube having an internal diameter of less than 5/8 inch shall be used. With lined conduit, this measurement is to be taken inside the metal tube.

It has been found in practice with sizes smaller than this, that the smallest wire permitted by Rule 14 *a*, page 55, cannot be readily drawn in and out of the conduit.

b. Must be continuous from outlet to outlet or to junction boxes, and the conduit tube must properly enter and be secured to all fittings.

In the case of underground 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. (See Rule 54, page 108.)

They must be continuous, in order that the wires may be readily drawn in after the conduit system is completed, and also to ensure that the wire is protected throughout its whole length.

25. **Interior Conduits** — *Continued.*

c. Must first be installed as a complete conduit system, without the conductors.

For the reason given under Rule 24 *o*, page 73.

d. Must be equipped at every outlet with an *approved* outlet box or plate. (See Rule 49 A, page 94.)

Outlet plates must not be used where it is practicable to install outlet boxes.

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.

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 the wire from abrasion, except when such protection is obtained by the use of *approved* nipples, properly fitted in the boxes or other devices.

f. The metal of the conduit must be permanently and effectually grounded.

It is essential that the metal of conduit systems be joined so as to afford electrical conductivity sufficient to allow the largest fuse or circuit-breaker in the circuit to operate before a dangerous rise in temperature in the conduit system can occur. Conduits and gas pipes must be securely fastened in metal outlet boxes so as to secure good electrical connection. Where boxes used for centres of distribution do not afford good electrical connection, the conduits must be joined around them by suitable bond wires. Where sections of metal conduit are installed without being fastened to the metal structure of buildings or grounded metal piping, they must be bonded together and joined to a permanent and efficient ground connection.

It is rarely possible to perfectly insulate a conduit system throughout, and a *positive* ground is therefore required, so as to provide a definite path for leaking currents and thus prevent them from escaping through parts of a building, etc., where they might do harm.

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 must not be less than 3½ inches. Must not have more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.

26. **Fixtures.**

(*See also Rules 22 e and 24 v to 24 x, pages 67 and 75.*)

a. Must, when supported from the gas piping or any grounded metal work of a building, be insulated from such piping or metal work by means of *approved* insulating joints (see Rule 59, page 114) placed as close as possible to ceiling or walls.

The gas outlet pipe 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.

26. **Fixtures**—*Continued.*

Where canopies are placed against plaster walls or ceilings in fireproof buildings, or against metal walls or ceilings, or plaster walls or ceilings on metallic lath in any class of buildings, they must be thoroughly and permanently insulated from such walls or ceilings.

Where incandescent lamp fixtures are hung from gas pipes or combined with gas fixtures, it is highly important to have them well insulated from the grounded portion of the gas pipe. If this is not done, any injury to the insulating covering of the wire inside the fixture would ground one side of the electric system, and this would probably result in dangerous arcs. Sometimes these arcs melt holes in the gas pipe and ignite the escaping gas. Most combination fixtures have not sufficient room in them to permit the use of wire having insulation of a standard thickness, and this increases the chances of the insulation becoming sufficiently abraded to allow the conductors to come in contact with the fixture. The best and usual way to insulate the fixture from the ground is by interposing between it and the gas supply pipes what is called an insulating joint, which is, in effect, a piece of gas pipe made of insulating material, such as porcelain or hard rubber.

b. Must have all burs or fins removed before the conductors are drawn into the fixtures.

Because such sharp edges are liable to cut and tear the insulation of the wire when it is drawn into the fixture or, in time, by jarring of the fixture after it is in position.

c. Must be tested for "contacts" between conductors and fixtures, for "short-circuits," and for ground connections, before they are connected to their supply conductors.

27. **Sockets.**

(*For construction requirements, see Rule 55, page 111.*)

a. In rooms where inflammable gases may exist, the incandescent lamp and the socket must be enclosed in a vapor-tight globe, and supported on a pipe-hanger wired with *approved* rubber-covered wire (see Rule 41, page 86) soldered directly to the circuit.

In Factory Mutual work, a pendant like that shown on page 80, using a standard *keyless* socket, or an approved waterproof pendant like those shown on page 79, will be accepted in place of the pipe-hanger, but the vapor-tight globe will be required in all cases. The reinforced cord or stranded waterproof conductors should not be smaller than No. 14 B. & S. gage in order to safely carry the added weight of the vapor-tight globe.

If a stiff pendant supported by a "crow-foot" or equivalent is used, the pipe should be as short as possible, as a long one is liable to be wrenched out of place, or the "crow-foot" broken, by even a light blow. The wires should be *stranded* and should not be smaller than No. 16 B. & S. gage. They should be thoroughly protected with insulating tape where they emerge from the top of the pipe,—the edges of which must be carefully smoothed off,—or else a regular conduit outlet bushing should be provided. The use of a good outlet bushing is preferred.

b. In damp or wet places, or over especially inflammable material, waterproof sockets must be used.

Waterproof sockets should 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 3 feet long. These wires should be soldered direct to the circuit wires, but supported independently of them.

This form of construction is clearly shown in Figs. 39 and 40, in which is also indicated a method of supporting the pendant so that all strain is removed from the connection to the overhead wires.

27. **Sockets**— *Continued.*

Attention is called to the note under Rule 28 *d*, for description of an approved pendant for use over especially inflammable material.

28. Flexible Cord.

a. Must have an *approved* insulation and covering. (See Rule 45, page 89.)

b. Must not 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.

It is not mechanically strong enough to safely sustain much weight.

FIG. 39.
SHORT WATERPROOF PENDANT.

d. Must not be used except for pendants, portable lamps or motors, and portable heating apparatus.

FIG. 40.
LONG WATERPROOF PENDANT, WIRES TWISTED TOGETHER.

The practice of making the pendants 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 the air, and the cord adjusters wear off the insulation very rapidly.

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 are on the market, and should be used. (See Rule 45 *f*, page 90.)

The standard socket is threaded for 1/8 inch pipe, and if it is properly bushed, the reinforced flexible cord will not go into it, but this style of cord may be used with sockets threaded for 3/8 inch pipe, and provided with substantial insulating bushings. The cable should be supported independently of the overhead circuit by a single-wire cleat, and the two conductors then separated and soldered to the overhead wires.

The bulb of an incandescent lamp frequently becomes hot enough to ignite paper, cotton, and similar readily ignitible materials, and in order to prevent it from coming in contact with such materials, as well as to protect it from breakage, every portable lamp should be surrounded with a substantial wire guard.

The chances for short-circuits in flexible cord are considerable, as the wires of opposite polarity are brought very near together. As a result of continued bending in handling, some of the fine wires may break, and the loose, sharp ends may then puncture the insulation and form a short-circuit with the other conductor. Or the insulation may deteriorate or become sufficiently worn to allow the bare wires to come into contact with each other. The arc formed at the instant the short-circuit occurs is liable to set fire to the insulation of the wire if it be at all of a combustible nature. This will sometimes occur even if the circuit is instantly opened by melting of the fuses. It is for these reasons that it is desirable to limit the use of flexible cord to those places where nothing else is suitable.

The type of pendant described above for portable work and illustrated in Fig. 41, page 80, is also recommended for use in all hazardous places, such as picker and carding rooms, napping rooms, dust chambers, woodworking shops, etc., and also for storehouses. Except in especially hazardous places, a ceiling rosette may be used in place of the soldered connections to the overhead wires.

28. **Flexible Cord**—*Continued.*

e. Must not be used in show windows.

Because a defective cord is very liable to set fire to the inflammable material about it. Records show an unfortunately large number of fires caused by the use of common flexible cord in show windows.

f. Must be protected by insulating bushings where it enters the socket.

The hole through which the wire must enter the socket is ordinarily threaded for attachment to fixtures. The sharp thread would soon cut through the insulation of the cord and cause a short-circuit, were it not for the bushing.

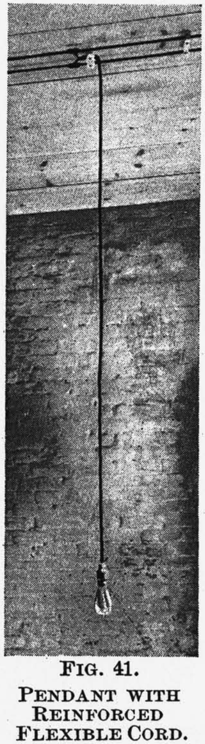


FIG. 41.
PENDANT WITH REINFORCED FLEXIBLE CORD.

g. Must be so suspended that the entire weight of the socket and lamp will be borne by knots, 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.

The electrical connection, which is generally made by clamping the fine wires under a flat-headed screw, has not sufficient mechanical strength to be trusted as a means of sustaining the weight of the lamp and fittings.

When knotting the cord, especially in the rosette, care should be taken to pull the knot hard against the porcelain, and with the knot in this position, to then fasten the wires under the binding screws. Unless this is done, the knot will probably not bear on the porcelain and will therefore be of no service in preventing the strain coming on the binding screws, which, in time, may result in a loose connection.

It is also a good practice to have the ends of the conductors dipped in melted solder where they are fastened under the binding screws. This binds the fine wires together and leaves no loose ends to make short-circuits inside the socket.

29. **Arc Lights on Constant-Potential Circuits.**

(*For construction requirements, see also Rule 57, page 114.*)

a. Must have a cut-out (see Rule 17 *a*, page 60) for each lamp or each series of lamps.

The branch conductors should have a carrying capacity about 50% in excess of the normal current required by the lamp, in order to guard against overheating the wires due to the large current required when the lamp is started or when the carbons become stuck.

Where it is necessary to use two or more arc lamps in series on constant-potential systems, the lamps should be so designed that if the arc is short-circuited, as for example when the carbons come together, a resistance equivalent to that of the arc will be automatically thrown in circuit, thus preventing the increase of current on this circuit which otherwise would result, and which might overheat the other lamps of the series. The fuses and switches should be suitable for the voltage of the supply mains.

The use of arc lamps in series on constant-potential systems is not advised, as higher voltages are then necessary throughout the buildings. Moreover in many places, the economical use of power with such an arrange-

29. **Arc Lights on Constant-Potential Circuits** — *Continued.*

ment would also be questionable. This system will be permitted in Factory Mutual risks only when the conditions are such that the use of single lamps in multiple is impracticable, and the lamps can be favorably located.

b. All resistances or regulators must be enclosed in non-combustible material and must be treated as sources of heat. Incandescent lamps must not be used for this purpose.

Even when the arc lamp is burning properly, these resistances are quite hot, and they may be melted by excessive current if the lamp fails to burn as it should.

For general inside use, especially in dusty or linty places, the casing about the resistances should be so constructed as to absolutely prevent the accumulation of lint, etc., inside, where it can become ignited, due to contact with the hot resistance. This is an important point, as several fires due to this cause have occurred where lamps with open casings have been used in textile mills. The switch on the lamp should also be enclosed so that lint cannot collect on it and be ignited when the switch is opened. The lamp as a whole should be so designed and installed that no part upon which combustible flyings may collect can become dangerously hot under conditions liable to be met with in practice.

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 Rules 19 and 58, pages 62 and 114.)

Outside arc lamps must be suspended at least 8 feet above sidewalks. Inside arc lamps must be placed out of reach or suitably protected.

The above requirements as to spark arresters, etc., would, of course, not apply to "enclosed arc" lamps having tight inner globes, except that a wire netting around the inner globe will generally be required if the outer globe is omitted.

In hazardous places such as picker and carding rooms, etc., the outer globe should be provided in order to keep flyings away from the hot inner globe and cap.

30. **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 1 inch between frame and support, and must, in general, be treated as sources of heat.

Practically the same precautions in locating and mounting these devices should be taken as with resistance boxes, etc. (See Rule 4, page 28.) This would require that they be mounted on a slate base or equivalent, which in turn is fastened to the wall or other support, the attachments to be independent of each other, and the base to be of such size as to give a continuous separation between the device and the support. It will not be satisfactory to mount these devices on porcelain knobs.

31. **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 that 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 1320 watts shall be dependent on one cut-out.

31. Decorative Lighting Systems—*Continued.*

No "System of Decorative Lighting" is to be allowed under this rule which is not listed in the Supplement to the National Electrical Code, containing a list of approved fittings.

The Factory Mutual Companies also publish a list of approved fittings which should be followed in all work in Mutual risks.

b. Incandescent lamps connected in series must not be used for decorative purposes inside of buildings, except by special permission in writing from the Inspection Department having jurisdiction.

32. Car Wiring.

a. Must always be run out of reach of the passengers, and must have an *approved* rubber insulating covering. (See Rule 41, page 86.)

33. 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 cannot be made with the floor.

c. Must have a cut-out switch located at a proper place outside of the building, so that all trolley circuits in the building can be cut out at one point, and line circuit-breakers must be installed, so that when this cut-out 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 whenever the latter is not in use or the road is not in operation.

d. All lamps and stationary motors must be installed in such a way that one main switch can control the whole of each installation — lighting or power — independently of the main feeder-switch. No portable incandescent lamps or twin wire will be allowed, except that portable incandescent lamps may be used in the pits, the circuit to be controlled by a switch placed outside of the pit, and the connections to be made by two *approved* rubber-covered flexible wires (see Rule 41, page 86), properly protected against mechanical injury.

e. All wiring and apparatus must be installed in accordance with rules for constant-potential systems.

f. Must not have any system of feeder distribution centring in the building.

g. The rails must be bonded at each joint with a conductor having a carrying capacity not less than that of a No. 2 B. & S. gage annealed copper wire.

h. Cars must not be left with the trolley in electrical connection with the trolley wire.

34. Lighting and Power from Railway Wires.

a. **Must not be permitted, under any pretense, in the same circuit with trolley wires with a ground return, except in electric railway cars, electric car houses, and their power stations, nor shall the same dynamo be used for both purposes.**

Lighting from trolley wires is forbidden because of the danger of introducing into a building a circuit which has so much capacity back of it and which is thoroughly connected with the earth on one side. The inevitable fluctuation in voltage would also frequently require overfusing of the lighting circuits to prevent blowing fuses under normal conditions.

HIGH-POTENTIAL SYSTEMS.

550 TO 3500 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 3500 volts, shall be considered as 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.

(See note following first paragraph under Low-Potential Systems, page 68.)

35. Wires.

(*See also Rules 14, 15 and 16, pages 55 and 58.*)

a. Must have an *approved* rubber insulating covering. (See Rule 41, page 86.)

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

c. Must be rigidly supported on glass or porcelain insulators which raise the wire at least 1 inch from the surface wired over, and must be kept about 8 inches apart.

Rigid supporting requires, under ordinary conditions, where wiring along flat surfaces, supports at least every 4½ feet. If the wires are unusually liable to be disturbed, the distance between supports should be shortened.

In buildings of mill construction, mains of No. 8 B. & S. gage wire or over, where not liable to be disturbed, may be separated about 10 inches and run from timber to timber, not breaking around, and may be supported at each timber only.

The proper distance between insulators depends largely on the surroundings. In places where ceilings are low, or where belts, shafting or other machinery may require frequent attention, insulators should be placed every few feet, in order to prevent the wires from being displaced by careless or unavoidable blows from workmen. On the other hand, with a high ceiling and no chance of derangement, a greater distance would be allowable.

The whole idea is to so rigidly secure the wires that they cannot come in contact with each other or any other conductors if loosened by shrinkage of timbers and floors, or by careless knocking.

The covering of the wires should not be depended on for insulation. The wire should be so supported on the glass or porcelain insulators that, even if it were bare, the insulation of the system would still be excellent. The office of the covering will then be chiefly to protect the wires from accidental contacts of any kind.

35. Wires — *Continued.*

d. Must be protected on side walls from mechanical injury by a substantial boxing, retaining an air space of at least 1 inch around the conductors, closed at the top (the wires passing through bushed holes) and extending not less than 7 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 ½ inch in thickness.

For general suggestions on protection, see note under Rule 24 *e*, page 69. See also note under Rule 18 *e*, page 61.

36. Transformers — *When permitted inside of buildings.*

(*For construction requirements, see Rule 62, page 117.*)
(*See also Rules 13 and 13 A, pages 50 and 52.*)

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.

This is to reduce the amount of high-voltage primary wire in the building to as small an amount as possible.

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 persons.

It is better to arrange the transformer room or enclosure so that it can be entered only from outdoors, since then, even if the door should happen to be open at the time of a fire in this room, it is probable that no especial harm would be done. Moreover, the fire could doubtless be better handled from the outside.

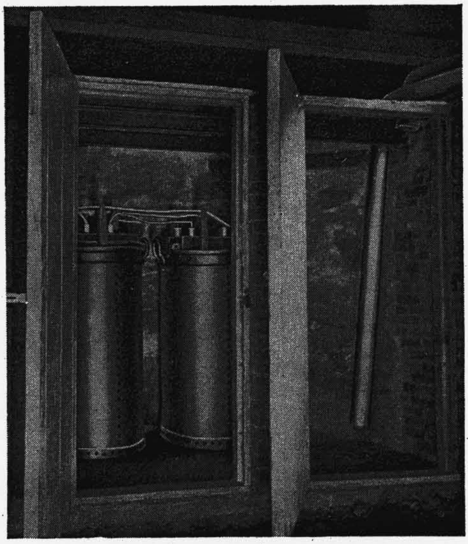


FIG. 42.
TRANSFORMER VAULT IN BASEMENT OF BUILDING.

c. Must be thoroughly insulated from the ground or permanently and effectively grounded, and the enclosure in which they are placed must be practically air-tight, except that it must be thoroughly ventilated to the out-door air, if possible, through a chimney or flue. There should be at least 6 inches air space on all sides of the transformer.

36. **Transformers** — *Continued.*

This rule will permit of either the insulating or grounding of transformer cases as seems most advisable under the conditions, but will require that with either arrangement the work be well done, and that unless good insulation be provided the cases be definitely grounded.

The object of an air-tight enclosure is to prevent smoke from escaping or fire from spreading, in case the transformer coils should become overheated from an overload or should be ignited by a break-down in the insulation between the primary and secondary coils. This is especially important with oil-cooled transformers, as explained in the note to Rule 11 *a*, page 39.

For requirements regarding grounding of transformer secondary circuits, see Rule 13 A *b*, page 52. See also note at head of Rule 13, page 50.

Fig. 31 shows a brick transformer vault with a standard fire door in front of each transformer. Attention is called to the high threshold, intended to prevent the escape of oil if one of the transformers should boil over. The two ventilator pipes, visible at the right of the cut and leading outdoors, are made of galvanized iron and are 5 inches in diameter.

37. Series Lamp.

a. No multiple-series or series-multiple system of lighting will be approved.

See note under Rule 20 *c*, page 63.

b. Must not, under any circumstances, be attached to gas fixtures.

See note under Rule 20 *d*, page 63.

EXTRA-HIGH-POTENTIAL SYSTEMS.

OVER 3500 VOLTS.

Any circuit attached to any machine or combination of machines, which develops a difference of potential, between any two wires, of over 3500 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 3500 volts or less.

38. Primary Wires.

a. Must not be brought into or over buildings, except power stations and sub-stations.

39. 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 3500 volts, unless the primary wires are installed in accordance with the requirements as given in Rule 12 *a*, page 43, or are entirely underground, within city, town and village limits.

In every case where it is desired to carry the secondary circuits of an extra-high-potential system into Factory Mutual risks, it is advised that the Inspection Department be consulted before the work of installation is begun, in fact, before the apparatus is even ordered. Each such case will be treated on its own merits and such precautions recommended as appear necessary to secure a safe arrangement. (See note at head of Rule 13, page 50.)

CLASS D.

FITTINGS, MATERIALS, AND DETAILS OF CONSTRUCTION.*

All Systems and Voltages.

Insulated Wires — Rules 40 to 48.

40. General Rules.

a. Copper for insulated conductors must never vary in diameter so as to be more than .002 inch less than the specified size.

b. Wires and cables of all kinds designed to meet the following specifications must be plainly tagged or marked as follows : —

1st. The maximum voltage at which the wire is designed to be used.

2d. The words "National Electrical Code Standard."

3d. The name of the manufacturing company and, if desired, the trade-name of the wire.

4th. The month and year when manufactured.

It is recommended that all wires complying with these specifications be provided with a distinctive marking on the insulation or braid which will serve to identify them at any time.

41. Rubber-Covered Wire.

a. Copper for conductors must be thoroughly tinned.

Insulation for voltages between 0 and 600.

b. Must be of rubber or other approved substance, and of a thickness not less than that given in the following table : —

B. & S. Gage.	Thickness.
18 to 16	1/32 inch.
15 " 8	3/64 "
7 " 2	1/16 "
1 " 0000	5/64 "
Circular Mils.	
250,000 to 500,000	3/32 "
500,001 " 1,000,000	7/64 "
Over 1,000,000	1/8 "

Measurements of insulating wall are to be made at the thinnest portion of the dielectric.

* In preparing Class D, the Underwriters have, from the beginning, received valuable aid from the manufacturers interested in the various fittings, and during the past few years there have been many instances of this coöperation. For example, in December, 1898, a special committee met the leading socket manufacturers and agreed on a complete set of specifications. Again, in January, 1899, another committee assembled in Chicago and discussed for several days, with representatives of the leading insulated wire manufacturers in the United States and Canada, specifications for insulations of various kinds and reached mutually satisfactory agreements. Similar coöperation with regard to switches, cut-outs, rheostats, and other fittings has been secured by conference and correspondence. Recently, the very important determination of the specifications for the "Standard Enclosed Fuse" has similarly been accomplished.

41. **Rubber-Covered Wire** — *Continued.*

c. The completed covering must show an insulation resistance of at least 100 megohms per mile during 30 days' immersion in water at 70° Fahr.

d. Each foot of the completed covering must show a dielectric strength sufficient to resist throughout 5 minutes the application of an electro-motive force of 3000 volts per 1/64 inch thickness of insulation, under the following conditions: —

The source of alternating electro-motive force shall be a transformer of at least 1 kilowatt capacity. The application of the electro-motive force shall first be made at 4000 volts for 5 minutes and then the voltage increased by steps of not over 3000 volts, each held for 5 minutes, until the rupture of the insulation occurs. The tests for dielectric strength shall be made on a sample of wire which has been immersed in water for 72 hours. One (1) 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.

Special attention is called to the fact that the above tests for dielectric strength are to be applied to only a single foot of the wire and are not intended to be applied to longer lengths; also, that the requirement of 3000 volts per 1/64 inch thickness of insulation does not apply to insulations thicker than 1/8 inch.

Insulations for voltages between 600 and 3500.

e. The thickness of the insulating wall must not be less than that given in the following table: —

B. & S. Gage.	Thickness.	
14 to 1	3/32 inch.	
0 to 0000	3/32 "	covered by tape or braid.
Circular Mils.		
250,000 to 500,000	3/32 "	" " "
Over 500,000	1/8 "	" " "

f. The requirements as to insulation and break-down resistance for wires for low-potential systems shall apply, with the exception that an insulation resistance of not less than 300 megohms per mile will be required.

Insulations for voltages over 3500.

g. Wire for arc light circuits exceeding 3500 volts potential must have an insulating wall not less than 3/16 inch in thickness, and must withstand a break-down test of at least 30,000 volts and have an insulation resistance of at least 500 megohms per mile.

The test on this wire is to be made under the same conditions as for low-potential wires.

Specifications for insulations for alternating currents exceeding 3500 volts have been considered, but on account of the somewhat complex conditions in such work, it has so far been deemed inexpedient to specify general insulations for this use.

41. Rubber-Covered Wire — *Continued.*

Protecting braid.

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 abrasion likely to be met with in practice, and sufficiently elastic to permit all wires smaller than No. 7 B. & S. gage to be bent around a cylinder of twice the diameter of the wire, without injury to the braid.

This is in addition to the tape or braid called for in § *e*.

42. Slow-Burning Weatherproof Wire.

a. The insulation shall consist of two coatings, one to be fireproof in character and the other to be weatherproof. The fireproof coating must be on the outside and must comprise about .6 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 " 2	1/16 "
1 " 0000	5/64 "
Circular Mils.	
250,000 to 500,000	3/32 "
500,001 " 1,000,000	7/64 "
Over 1,000,000	1/8 "

Measurements of insulating wall are to be made at the thinnest portion of the dielectric.

This wire is not as burnable as "weatherproof," nor as subject to softening under heat. It is not suitable for outside work.

Fire will not run along this wire under ordinary conditions, and lint will not adhere to its hard, smooth outer surface. It is therefore an excellent wire for general use in dry places on low-potential systems where the "open" cleat style of wiring is adopted. (See note under Rules 2 *b* and 24 *g*, pages 25 and 72.)

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."

43. Slow-Burning Wire.

a. The insulation must consist of layers of cotton or other thread, all the interstices of which must be filled with the fireproofing compound, or of material having equivalent fire-resisting and insulating properties. The outer layer must be braided and specially designed to withstand abrasion. The thickness of insulation must not be less than that required for

43. **Slow-Burning Wire** — *Continued.*

"Slow-Burning Weatherproof Wire," and the outer surface must be finished smooth and hard.

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° Fahr. and which will not burn at even a higher temperature.

"Slow-Burning Wire" must not be used without special permission from the Inspection Department having jurisdiction.

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 or weatherproof insulations would result in an objectionably large mass of highly inflammable material. Its use is restricted, as its insulating qualities are not high and are diminished by moisture.

Slow-burning wire has practically the same advantages as slow-burning weatherproof wire as regards the carrying of fire and the non-adhesion of flyings. Under most conditions, however, the latter wire is preferred, as its insulation is somewhat higher and it will withstand moisture better.

See also note under Rule 2 *b*, page 25.

44. Weatherproof Wire.

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 retain its elasticity at 0° Fahr. and must not drip at 160° Fahr. The thickness of insulation must not be less than that required for "Slow-Burning Weatherproof Wire," 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.

45. Flexible Cord.

(*For installation requirements, see Rule 28, page 79.*)

a. Must be made of stranded copper conductors, each strand to be not larger than No. 26 nor smaller than No. 30 B. & S. gage, and each stranded conductor must be covered by an *approved* insulation and protected from mechanical injury by a tough, braided outer covering.

For pendant lamps.

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.

b. Each stranded conductor must have a carrying capacity not less than that of a No. 18 B. & S. gage wire.

45. **Flexible Cord** — *Continued.*

c. The covering of each stranded conductor must be made up as follows: —

1st. A tight, close wind of fine cotton.
2d. The insulation proper, which shall be waterproof.
3d. An outer cover of silk or cotton.

The wind of cotton tends to prevent a broken strand from puncturing the insulation and causing a short-circuit. It also keeps the rubber from corroding the copper.

d. The insulation must be solid, at least 1/32 inch thick, and must show an insulation resistance of 50 megohms per mile throughout 2 weeks' immersion in water at 70° Fahr. It must also stand the tests prescribed for low-tension wires, as far as they apply.

e. The outer protecting braiding should be so put on and sealed in place that when cut it will not fray out, and where cotton is used, it should be impregnated with a flame-proof paint which will not have an injurious effect on the insulation.

The object of the flame-proof paint is obviously to make the cord as slow-burning as practicable, and any other method of treating the outer cotton cover which will accomplish this result will of course be acceptable. In no case, however, should the treatment be such that the rubber insulation is injured, or the flexibility or wearing qualities of the cord eventually lessened.

For portables.

In this class is included all cord used on portable lamps, small portable motors, or any device which is liable to be carried about.

It includes also all pendant cords which are liable to be hung over nails, machinery, etc.

f. Flexible cord for portable use must 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. There must also be an extra layer of rubber between the outer cover and the flexible cord, and in moist places the outer cover must be saturated with a moisture-proof compound, thoroughly slicked down, as required for "Weatherproof Wire" in Rule 44, page 89. In offices, dwellings, or similar places where the appearance is an essential feature, a silk cover may be substituted for the weatherproof braid.

For Factory Mutual work, except in offices, etc., the saturation and finishing of the outer cover as above mentioned will generally be required, even in dry places, as the wearing qualities are thereby increased and when cut or worn the cover will not fray out so quickly.

For portable heating apparatus.

g. Must be made up as follows: —
1st. A tight, close wind of fine cotton.
2d. A thin layer of rubber or other cementing material about 1/100 inch thick.

45. **Flexible Cord** — *Continued.*

3d. A layer of asbestos insulation at least $\frac{3}{64}$ inch thick.
4th. A stout braid of cotton.
5th. An outer reinforcing cover especially designed to withstand abrasion.

This cord is in no sense waterproof, the thin layer of rubber being intended merely to serve as a seal to help hold in place the fine cotton and asbestos. The rubber or equivalent should be put on in such a way as will accomplish this object.

In order that the cord as a whole shall be as slow-burning as possible the cotton should be treated as required for flexible cord for pendant lamps. In order to reduce the liability of abrasion of the outer covering of the cord in spots, it is recommended that an asbestos filler be twisted in with the two conductors so as to secure a more nearly circular cross section.

46. Fixture Wire.

(*For installation requirements, see Rules 24 v to 24 y, page 75.*)

a. 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.

b. Solid conductors must be thoroughly tinned. If a stranded conductor is used, it must be covered by a tight, close wind of fine cotton.

c. Must have a solid rubber insulation of a thickness not less than $\frac{1}{32}$ inch for Nos. 18 to 16 B. & S. gage, and $\frac{3}{64}$ inch for Nos. 14 to 8 B. & S. gage, except that in arms of fixtures not exceeding 24 inches in length and used to supply not more than one sixteen candle-power lamp or its equivalent, which are so constructed as to render impracticable the use of a wire with $\frac{1}{32}$ inch thickness of rubber insulation, a thickness of $\frac{1}{64}$ inch will be permitted.

d. Must be protected with a covering at least $\frac{1}{64}$ 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.

e. Must successfully withstand the tests specified in Rules 41 *c* and 41 *d*, page 87.

47. Conduit Wire.

(*For installation requirements, see Rules 24 n to 24 p, pages 73 and 74.*)

a. Single wire for lined conduits must comply with the requirements of Rule 41, page 86. 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 $\frac{1}{32}$ inch in thickness and sufficiently tenacious to withstand the abrasion of being hauled through the metal conduit.

47. **Conduit Wire** — *Continued.*

b. For twin or duplex wires in lined conduit, each conductor must comply with the requirements of Rule 41, page 86, — except that tape may be substituted for braid on the separate conductors, — and must have a substantial braid covering the whole. For unlined conduit, each conductor must comply with the requirements of Rule 41, — except that tape may be substituted for braid, — and in addition must have a braid covering the whole, at least 1/32 inch in thickness and sufficiently tenacious to withstand the abrasion of being hauled through the metal conduit.

c. For concentric wire, the inner conductor must comply with the requirements of Rule 41, page 86, — 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 1/32 inch in thickness and sufficiently tenacious to withstand the abrasion of being hauled through the metal conduit.

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.

48. Armored Cables.

(*For installation requirements, see Rule 24 A, page 75.*)

a. The armor of such cables must have at least as great strength to resist penetration of nails, etc., as is required for metal conduits (see Rule 49 *b*, page 93), and its thickness must not be less than that specified in the following table: —

Nominal Internal Diameter. Inches.	Actual Internal Diameter. Inches.	Actual External Diameter. Inches.	Thickness of Wall. Inches.
1/8	.27	.40	.06
1/4	.36	.54	.08
3/8	.49	.67	.09
1/2	.62	.84	.10
3/4	.82	1.05	.11
1	1.04	1.31	.13
1 1/4	1.38	1.66	.14
1 1/2	1.61	1.90	.14
2	2.06	2.37	.15
2 1/2	2.46	2.87	.20
3	3.06	3.50	.21
3 1/2	3.54	4.00	.22
4	4.02	4.50	.23
4 1/2	4.50	5.00	.24
5	5.04	5.56	.25
6	6.06	6.62	.28

An allowance of .02 inch for variation in manufacturing and loss of thickness by cleaning will be permitted.

b. The conductors in same, single wire or twin conductors, must have an insulating covering as required by Rule 41, page 86. If any filler is used to secure a round exterior, it must be

48. **Armored Cables** — *Continued.*

impregnated with a moisture repellent, and the whole bunch of conductors and fillers must have a separate exterior covering.

Very reliable insulation is specified, for the reason that such cables are liable to receive hard usage, and in any part of their length may be subject to moisture. In many cases they are not easily removable, so that a breakdown of insulation is likely to be expensive as well as troublesome.

49. Interior Conduits.

(*For installation requirements, see Rule 25, page 76.*)

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 detached in the ordinary handling of the conduit.

This requirement makes it difficult for irresponsible makers to successfully get their products on the market, and renders it possible to place the responsibility for faulty pieces.

Metal conduits with lining of insulating material.

b. The metal covering or pipe must be at least as strong as the ordinary commercial forms of gas pipe of the same size, and its thickness must be not less than that of standard gas pipe as specified in the table given in Rule 48, page 92.

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. The insulating lining must be firmly secured to the pipe.

e. The insulating lining must not crack or break when a length of the conduit is uniformly bent, at a temperature of 212° Fahr., to an angle of 90°, with a curve having a radius of 15 inches for pipes of 1 inch or less, and fifteen times the diameter of the pipe for larger sizes.

f. The insulating lining must not soften injuriously at a temperature below 212° Fahr., and must leave water in which it is boiled practically neutral.

g. The insulating lining must be at least 1/32 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 must be sufficiently tough and tenacious to withstand the abrasion test of drawing long lengths of conductors in and out of the same.

h. The insulating lining must not be mechanically weak after 3 days' submersion in water, and, when removed from the pipe entire, must not absorb more than 10% of its weight of water during 100 hours of submersion.

49. **Interior Conduits**— *Continued.*

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 3½ inches.

Unlined metal conduits.

j. Plain iron or steel pipes of thicknesses and strengths equal to those specified for lined conduits in § *b* may be used as conduits, provided their interior surfaces are smooth and free from burs. In order to prevent oxidation, the pipe must be galvanized, or the interior surfaces coated or enameled with some substance which will not soften so as to become sticky and prevent the wire from being withdrawn from the pipe.

k. 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 must not be less than 3½ inches.

49 A. Switch and Outlet Boxes.

a. Must be of pressed steel having a wall thickness not less than .081 inch (No. 12 B. & S. gage) or of cast metal having a wall thickness not less than .128 inch (No. 8 B. & S. gage).

b. Must be well galvanized, enameled or otherwise properly coated, inside and out, to prevent oxidation.

c. Inlet holes must be effectually closed, when not in use, by metal which will afford protection substantially equivalent to that of the walls of the box.

d. Must be plainly marked, where it may readily be seen when installed, with the name or trade-mark of the manufacturer.

e. Must be arranged to secure in position the conduit or flexible tubing protecting the wire.

In boxes of the "knockout" type, this rule will be complied with if the conduit or tubing is firmly secured in position by means of approved clamps. The clamps need 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 1/32 inch thick, firmly secured in position.

g. 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.

50. Wooden Mouldings.

(*For wiring requirements, see Rules 24 l and 24 m, page 73.*)

a. Must have, both outside and inside, at least two coats of waterproof paint, or be impregnated with a moisture repellent.

This is necessary in order to fill up the pores of the wood and prevent the possibility of its becoming saturated with water.

50. **Wooden Mouldings** — *Continued.*

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 and provide a tongue at least ½ inch wide between the conductors, and a solid backing, which, under grooves, shall not be less than ⅜ inch in thickness.

It is recommended that only hardwood moulding be used.

50 A. Tubes and Bushings.

a. **Construction.** — 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 water at 70° Fahr., will not absorb over ½ % of its weight.

c. **Marking.** — Must have the name, initials or trade-mark of the manufacturer stamped in the ware.

So that inspectors may know who is responsible for defective fittings.

d. **Sizes.** — Dimensions of walls and heads must be at least as great as those given in the following table: —

Diameter of Hole. Inches.	External Diameter. Inches.	Thickness of Wall. Inches.	External Diameter of Head. Inches.	Length of Head. Inches.
5/16	9/16	1/8	13/16	1/2
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 1/64 inch for variation in manufacturing will be permitted, except in the thickness of the wall.

50 B. Cleats.

a. **Construction.** — 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° Fahr., will not absorb over ½ % of its weight.

50 B. **Cleats** — *Continued.*

d. **Marking.** — Must have the name, initials or trade-mark of the manufacturer stamped in the ware.

For the same reason as given under Rule 50 A *c*, page 95.

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 an Edison three-wire system in the centre 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 2½ inches.

50 C. **Flexible Tubing.**

The following specifications are designed to cover the construction of flexible tubes for fished work, loop system, and for mechanical protection to wires where not exposed to moisture.

Tubes complying with these requirements must not be used for a conduit system of wiring.

a. Must be constructed to meet the following requirements: —

1. Must have a sufficiently smooth interior surface to allow the ready introduction of the wire.
2. Must be constructed of or treated with materials which will serve as moisture repellents.
3. Must have a substantial outer covering especially designed to withstand abrasion.

b. The linings must be secured in position so that they cannot be readily removed.

c. The tube must be thoroughly flexible at all temperatures at which it is to be used.

d. Must not crack or break when kinked or flattened out.

e. Must be sufficiently tough and tenacious to withstand severe tension without injury; the interior diameter must not be diminished or the tube opened up at any point by the application of a reasonable stretching force.

f. Must not close to prevent the insertion of the wire after the tube has been kinked and straightened out, or flattened.

g. Must not soften injuriously, or cause the wire to stick within the tube when subjected to a temperature of 150° Fahr.

51. **Switches.**

(*For installation requirements, see Rules 17 and 22, pages 60 and 65.*)

General Rules.

a. When used for service switches, must indicate whether the current is "on" or "off."

51. **Switches** — *Continued.*

b. For constant-current systems, must close the main circuit and disconnect the branch wires when turned "off"; must be so constructed that they shall be automatic in action, not stopping between points when started; must prevent an arc between the points under all circumstances; and must indicate whether the current is "on" or "off."

Knife Switches.

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 § *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, such as slate or porcelain. Bases with an area of over 25 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 ½ 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 ⅛ inch, and covered with a waterproof compound which will not melt below 150° Fahr.

If the contact jaws or hinge clips get turned so as to be out of line, it may be impossible to close the switch, especially at the first attempt, and severe arcing may result from the efforts to do so. Even if the blade enters the jaws, the contact may be imperfect, causing undesirable heating.

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, 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 for preventing rise in temperature of any part more than 50° Fahr. at full load, the contacts being so arranged that a thoroughly good bearing at every point is obtained, with contact surfaces advised for pure copper blades of about 1 square inch for each 75 amperes. The whole device must be mechanically well made throughout.

Too little attention is frequently given the question of mechanical strength, with the result that after a comparatively short time of service

51. **Knife Switches** — *Continued.*

the switches rattle to pieces or break unless very carefully handled, and even then repairs are often necessary to keep them in working order. A cheap switch is seldom a rugged, durable device.

g. **Cross-Bars.** — All cross-bars less than 3 inches in length must be made of insulating material. Bars of 3 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.

If each blade is secured to the cross-bar by only one screw, without dowel-pins or a square shoulder fitting closely in a recess in the bar, a slight loosening of the screws will allow one blade to close and open the circuit before the other, resulting in arcing and ultimate injury to the switch. Such construction is also liable to result in a weak switch.

h. **Connections.** — Switches for currents of over 30 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 that they are heavy enough to withstand 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 turned up lugs on the switch terminal gives a satisfactory contact.

See also Rule 14 *c*, page 55.

i. **Test.** — Must operate successfully at 50% overload in amperes and 25% excess voltage, under the most severe conditions 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 voltage for which the switch is designed.

This is to prevent mistakes and the accidents which are likely to follow if switches are used under conditions for which they were not designed. The name of the maker renders it possible to place the responsibility for defects.

k. **Spacings.** — Spacings must be at least as great as those given in the following table. The spacings specified are correct for switches to be used on direct-current systems, and can therefore be safely followed in devices designed for alternating currents.

51. **Knife Switches** — *Continued.*

	Minimum Separation of Nearest Metal Parts of Opposite Polarity.	Minimum Break-Distance.
125 VOLTS OR LESS:		
For Switchboards and Panel Boards: —		
10 amperes or less	¾ inch	½ inch.
11–25 amperes	1 "	¾ "
26–50 "	1¼ "	1 "
For Individual Switches: —		
10 amperes or less	1 inch	¾ inch.
11–35 amperes	1¼ "	1 "
36–100 "	1½ "	1¼ "
101–300 "	2¼ "	2 "
301–600 "	2¾ "	2½ "
601–1000 "	3 "	2¾ "
126 TO 250 VOLTS:		
For All Switches: —		
10 amperes or less	1½ inch	1¼ inch.
11–35 amperes	1¾ "	1½ "
36–100 "	2¼ "	2 "
101–300 "	2½ "	2¼ "
301–600 "	2¾ "	2½ "
601–1000 "	3 "	2¾ "

For 100 ampere switches and larger, the above spacings for 250 volts direct current are also approved for 440 volts alternating current. Switches with these spacings intended for use on alternating-current systems with voltage above 250 must be stamped with the voltage for which they are designed, followed by the letters "A. C."

251 TO 600 VOLTS:		
For All Switches: —		
10 amperes or less	3½ inch	3 inch.
11–35 amperes	4 "	3½ "
36–100 "	4½ "	4 "

Auxiliary breaks or the equivalent are recommended for switches designed for over 300 volts and less than 100 amperes, and will be required on switches designed *for use in breaking currents* greater than 100 amperes at a pressure of more than 300 volts.

For three-wire Edison 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.

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 ⅛ inch. There must in no case be less than 3/64 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 ½ inch from the surface wired over, must be furnished with all snap switches used in exposed knob or cleat 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-

51. **Snap Switches** — *Continued.*

heads on the under side of the base must be countersunk not less than 1/8 inch, and covered with a waterproof compound which will not melt below 150° Fahr.

n. **Metal.** — All switches must have ample metal for stiffness and for preventing rise in temperature of any part of more than 50° Fahr. at full load, the contacts being arranged so that a thoroughly good bearing at every point is obtained. The whole device must be mechanically well made throughout.

In order to meet the above requirements on temperature rise without causing excessive friction and wear on the current-carrying parts, contact surfaces of from .10 to .15 square inch for each 10 amperes will be required, depending upon the metal used and the form of construction adopted.

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° Fahr.

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.

q. **Covers.** — Covers made of conducting material, except face plates for flush switches, must be lined on sides and top with tough and tenacious insulating material at least 1/32 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.

Without this lining there is danger of the cover forming a short-circuit in the switch, especially if the cover is removed or replaced while the switch is "alive." The side lining should extend at least 3/64 inch 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.

Must operate successfully at 50 % overload in amperes and 25 % excess voltage, under the most severe conditions which they are liable to meet in practice.

When slowly turned "on and off" at the rate of about two or three times per minute, while carrying the rated current, must "make and break" the circuit 6000 times before failing.

The above endurance test should, of course, be made at the voltage for which the switch is rated.

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 back of the face plate or on the sub-plate. On other types they must be placed on the *front* of the cap, cover, or plate.

51. **Snap Switches** — *Continued.*

Switches which indicate whether the current is "on" or "off" are recommended.

Indicating switches are much preferred for all work, as by showing at once whether the current is "on" or "off" they tend to save mistakes and possible accidents. The fact that lights do not burn or that a motor does not run is not necessarily a sure sign that the current is off, but the indicating switch makes it possible to tell at a glance whether the circuit is open or closed.

52. Cut-Outs and Circuit-Breakers.

(*For installation requirements, see Rules 17 and 21. pages 60 and 63.*)

General Rules.

a. Must be supported on bases of non-combustible, non-absorptive, insulating material.

b. Cut-outs must be of the plug or cartridge type, when not enclosed 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 which they are liable to meet in practice, at 25 % above their rated voltage; and for link-fuse cut-outs, with fuses rated at 50 % 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 in the cut-out than that for which it was designed, which is not true of enclosed-fuse cut-outs classified as required in § *q*. 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 § *j*.)

d. Circuit-breakers must operate successfully on short-circuits, under the most severe conditions which they are liable to meet in practice, at 25 % above their rated voltage and with the circuit-breakers set at the highest possible opening point.

For the same reason as in § *c*.

e. Must be plainly marked, where it will always be visible, with the name of the maker and the current and voltage for which the device is designed.

For the same reasons that similar requirements were made for switches. (See note under Rule 51 *j*, page 98.)

It is also desirable to mark cut-outs on completed systems with the size of fuse which should be used in them. This will lessen the liability of a melted fuse being replaced with one too large to properly protect the wires.

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,

52. **Link-Fuse Cut-Outs** — *Continued.*

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 Rule 54, page 108. 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.

f. **Base.** — Must be mounted on slate or marble bases. Bases with an area of over 25 square inches must have at least four supporting screws. Holes for supporting screws must 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 ½ inch space, measured over the surface, between the head of the screw or washer and the nearest live part.

The proper thickness of the base depends very largely upon the size of the cut-out, but even for the smaller sizes the bases should generally be at least ⅜ inch thick.

g. **Mounting.** — Nuts or screw-heads on the under side of the base must be countersunk not less than ⅛ inch and covered with a waterproof compound which will not melt below 150° Fahr.

h. **Metal.** — All fuse-block terminals must have ample metal for stiffness and for preventing rise in temperature of any part of more than 50° Fahr. 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 winged 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.

i. **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 30 amperes, lugs firmly screwed or bolted to the terminals and into which the conducting wires are soldered must be used.

See note under Rule 51 *h*, page 98.

See also Rule 14 *c*, page 55, regarding soldering of wires at terminal connections.

j. **Test.** — Must operate successfully, when blowing only one fuse at a time on short-circuits, at 25% above their rated voltage, and with fuses rated at 50% above the current for which the cut-out is designed.

k. **Marking.** — Must be plainly marked, where it may readily be seen when the fuse-block is installed, with the name of the maker and the current and voltage for which the block is designed.

Plain and proper marking is especially important with cut-out blocks, as without it there is danger that the blocks will be fused for a greater

52. **Link-Fuse Cut-Outs** — *Continued.*

current or used on a higher voltage than those for which they were designed.

l. **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 spacings 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.
125 VOLTS OR LESS:		
10 amperes or less	¾ inch	¾ inch.
11-100 amperes	1 "	¾ "
101-300 "	1 "	1 "
301-1000 "	1¼ "	1¼ "
126 TO 250 VOLTS:		
10 amperes or less	1½ inch	1¼ "
11-100 amperes	1¾ "	1¼ "
101-300 "	2 "	1½ "
301-1000 "	2½ "	2 "

A space must be maintained between fuse terminals of the *same polarity* of at least ½ inch for voltages up to 125 and of at least ¾ 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 ⅛ inch in thickness, must be placed in the "break" gap, — this barrier to extend out from the base at least ⅛ inch farther than any bare live part of the fuse-block terminal, including binding screws, nuts, and the like.

For three-wire Edison systems, cut-outs must have the break-distance required for circuits of the potential of the outside wires.

With three-wire Edison systems, unless the break-distance of the cut-outs is designed for the potential of the outside wires, dangerous arcing at the cut-outs is liable to occur, especially where the neutral wire is not grounded, due to the grounding or short-circuiting of the outside wires so as to blow only one fuse on the higher voltage. Although the chance of such an occurrence is less with a grounded neutral, it is possible even here.

Enclosed-Fuse Cut-Outs, — Plug and Cartridge Type.

m. **Base.** — Must be made of non-combustible, non-absorptive, insulating material. Blocks with an area of over 25 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 ½ 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.

n. **Mounting.** — Nuts or screw-heads on the under side of the base must be countersunk at least ⅛ inch and covered with a waterproof compound which will not melt below 150° Fahr.

o. **Terminals.** — Terminals must be of either the Edison plug, spring clip, or knife blade type, of approved design, to take the

52. **Enclosed-Fuse Cut-Outs** — *Continued.*

corresponding standard 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.

This rule regarding design of terminal will be included in the specifications for the Standard enclosed-fuse cut-out above mentioned, and will apply to all capacities.

p. **Connections.** — Clamps for connecting wires to the terminals must be of a design which will insure a throughly good connection, and must be sufficiently strong and heavy to withstand considerable hard usage. For fuses rated to carry over 30 amperes, lugs firmly screwed or bolted to the terminals and into which the connecting wires shall be soldered must be used.

See also Rule 14 *c*, page 55, and note to Rule 51 *h*, page 98.

It is recommended that the clamps for the main wires in branch cutouts be designed to securely hold a wire at least as large as No. 0 B. & S. gage; for it is frequently desired to connect such cut-outs to these larger wires. If the clamps are poor or are too small, loose connections and heating may result, or some less desirable method of wiring may be used.

q. **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.

0 to 250 VOLTS:	251 to 600 VOLTS:
0–2 amperes.	0–2 amperes.
3–30 "	3–30 "
31–60 "	31–60 "
61–100 "	61–100 "
101–200 "	101–200 "
201–400 "	201–400 "
401–600 "	

r. **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.

s. **Marking.** — Must be marked, where it will be plainly visible when the block is installed, with the name of the maker and the voltage and range of current for which the block is designed.

53. Fuses.

(For installation requirements, see Rules 17 and 21, pages 60 and 63.)

Link Fuses.

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% of the maximum current which they can carry indefinitely, thus allowing about 25% overload before the fuse melts.

53. **Link Fuses** — *Continued.*

With naked open fuses, of ordinary shapes and with not over 500 amperes capacity, the *minimum* current which will melt them in about 5 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.

For reasons entirely similar to those given under Rule 51 *j*, page 98.

Enclosed Fuses, — Plug and Cartridge Type.

See note preceding Rule 52 *m*, page 103.

d. **Construction.** — The fuse plug or cartridge must be sufficiently dust-tight so that lint and dust cannot collect around the fusible wire and become ignited when the fuse is blown.

The fusible wire must be attached to the plug or cartridge terminals in such a way as to secure a thoroughly good connection and to make it difficult for it to be replaced when melted.

The fuse casing should also be so tight that the requirements for test (see § k) may be fulfilled.

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 ensure mechanical strength and rigidity. The styles of terminals must be as follows: —

0-250 Volts.

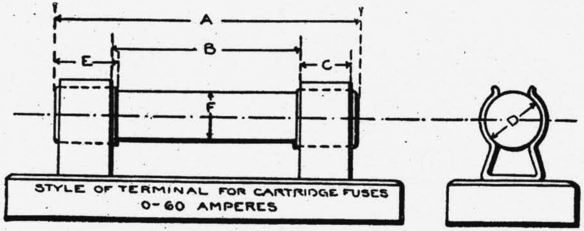
0–2 amps.	Cartridge fuse (ferrule contact)	to fit spring clipter minals.
3–30 "	*A* Cartridge fuse (ferrule contact) to fit	*a*, spring clip terminals. *b*, Edison plug casings.
	B Present Edison plugs, 0–125 volts.	
31–60 "	Cartridge fuse (ferrule contact) to fit	*a*, spring clip terminals. *b*, Edison plug casings.
61–100 " 101–200 " 201–400 " 401–600 "	Cartridge fuse (knife-blade contact).	

251-600 Volts.

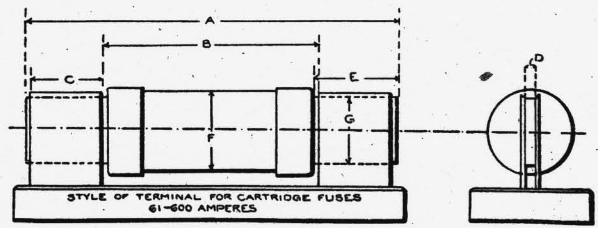
0–2 amps. 3–30 " 31–60 "	Cartridge fuse (ferrule contact).
61–100 " 101–200 " 201–400 "	Cartridge fuse (knife-blade contact).

g. **Dimensions.**—Cartridge enclosed fuses and corresponding cut-out blocks must conform to the dimensions given in the table on page 106.

53. **Enclosed Fuses** — *Continued.*



Form 1. CARTRIDGE FUSE — Ferrule Contact.



Form 2. CARTRIDGE FUSE — Knife-Blade Contact.

Voltage.	Rated Capacity. Amperes.		A Length over Terminals. Inches.	B Distance between Contact Clips. Inches.	C Width of Contact Clips. Inches.	D Diameter of Ferrules or Thickness of Terminal Blades. Inches.	E Min. Length of Ferrules or of Terminal Blades outside of Tube. Inches.	F Diameter of Tube. Inches.	G Width of Terminal Blades. Inches.		Rated Capacity. Amperes
0–250	0–2*	Form 1								Form 1	0–2*
	3–30		2	1	½	9/16	½	½			3–30
	31–60		3	1¾	⅝	13/16	⅝	¾			31–60
	61–100	Form 2	5⅞	4	⅞	⅛	1	1	¾	Form 2	61–100
	101–200		7⅛	4½	1¼	3/16	1⅜	1½	1⅛		101–200
	201–400		8⅝	5	1¾	¼	1⅞	2	1⅝		201–400
	401–600		10⅜	6	2⅛	¼	2¼	2½	2		401–600
251–600	0–2*	Form 1								Form 1	0–2*
	3–30		5	4	½	13/16	½	¾			3–30
	31–60		5½	4¼	⅝	1 1/16	⅝	1			31–60
	61–100	Form 2	7⅞	6	⅞	⅛	1	1¼	¾	Form 2	61–100
	101–200		9⅝	7	1¼	3/16	1⅜	1¾	1⅛		101–200
	201–400*										201–400*

* Dimensions of these fuses to be reported upon later.

53. **Enclosed Fuses** — *Continued.*

h. **Rating.** — Must be so constructed that with the surrounding atmosphere at a temperature of 75° Fahr. they will carry indefinitely a current 10 % greater than that at which they are rated, and at a current 15 % 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 % greater than the rating and room temperature 75° Fahr., fuses, starting cold, must blow within the time specified below: —

0–30 amperes	30 seconds.	101–200 amperes	4 minutes.
31–60 "	1 minute.	201–400 "	8 "
61–100 "	2 "	401–600 "	10 "

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° Fahr. 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 having a capacity of 300 K. W. or over, at the voltage for which the fuse is rated.

The above requirement that the testing circuit must have a capacity of at least 300 K. W. 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. A more definite rule regarding the conditions of this test is desirable, and the matter is under consideration. In any case, the test should be arranged to best represent the severer conditions of actual practice, not, however, including central station equipments, where specially designed and stronger fuses are undoubtedly necessary.

53 A. Tablet and Panel Boards.

The following minimum distances between bare live metal parts (bus-bars, etc.) must be maintained: —

Voltage.	Between parts of opposite polarity, except at switches and link fuses.		Between parts of same polarity.
	When mounted on the same surface.	When held free in the air.	At link fuses.
0–125	¾ inch	½ inch	½ inch.
126–250	1¼ "	¾ "	¾ "

53 A. **Tablet and Panel Boards** — *Continued.*

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 Rules 51 *k* and 52 *l*, pages 98 and 103.

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.

The fuses and switches should be so placed relatively to the bus-bars that the switches will be properly protected by the fuses; that is, the fuses should be placed between the bus-bars and the switches.

54. Cut-Out Cabinets.

a. **Material.** — Cabinets must be substantially constructed of non-combustible, non-absorptive material, or of wood. When wood is used the inside of the cabinet must be completely lined with a non-combustible insulating material. Slate or marble at least ¼ inch in thickness is strongly recommended for such lining, but, except with metal conduit systems, asbestos board at least ⅛ inch in thickness may be used in dry places if firmly secured by shellac and tacks.

With metal conduit systems the lining of either the box or the gutter must be of galvanized, painted or enameled iron, 1/16 inch thick, or preferably of slate or marble, ¼ inch thick.

The object of the lining of such cut-out cabinets or gutters is to render them practically fireproof in case of a short-circuit after the wires leave the protecting metal conduits.

With wooden cabinets, the wood should be thoroughly filled and painted before the lining is put in place.

In Factory Mutual mills, the asbestos-board or slate lining in wooden cabinets will only be required where link fuses or knife switches are used. Link fuses throw out melted metal when they operate, which makes the fireproofing advisable. Under some conditions there is also considerable flame when knife switches are opened, especially the larger sizes, which might be objectionable if the switches were located near the woodwork. However, the fireproofing of switch cabinets will not be required where the conditions are favorable and the above objections do not apply.

With approved enclosed fuses or snap switches this protection is not considered necessary, although the cabinets should be painted at least two coats of some good lead or fireproof paint both inside and outside. This will not only give some protection against a flash fire, but will largely prevent the inevitable changes in atmospheric conditions from opening up cracks through which lint and dust may enter. Only well seasoned stock should be used in the construction of these wooden cabinets.

b. **Door.** — The door must close against a rabbet, so as to be perfectly dust-tight. Strong hinges and a strong hook or catch are required. Glass doors must be glazed with heavy plate glass, not less than 3/16 inch in thickness, and panes should not exceed 1 foot in width. A space of at least 2 inches must be allowed between the fuses and the door. This is necessary to prevent cracking or breaking by the severe blow and intense heat which may be produced under some conditions.

54. **Cut-Out Cabinets** — *Continued.*

A cabinet is of little use unless the door is kept tightly closed, and special attention is therefore called to the importance of having a strong and reliable catch or other fastening. A spring catch is advised if a good one can be obtained, but most of those sold for use on cupboards, etc., are so small that they fail to catch when the door shrinks a little, or are so weak that they soon give out.

c. **Bushings.** — Bushings through which wires enter must fit tightly the holes in the box, and must be of approved construction. The wires should completely fill the holes in the bushings, using tape to build up the wire, if necessary, so as to keep out the dust.

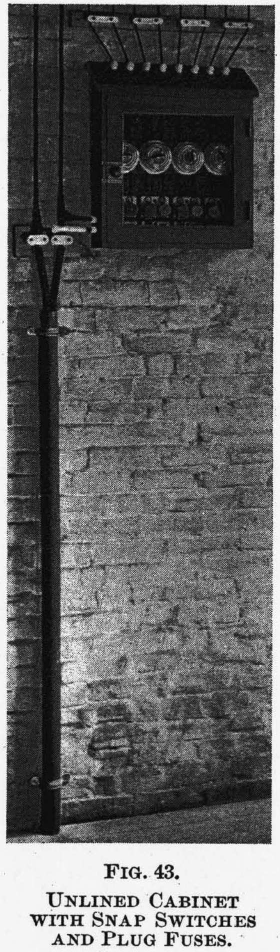


FIG. 43.

UNLINED CABINET WITH SNAP SWITCHES AND PLUG FUSES.

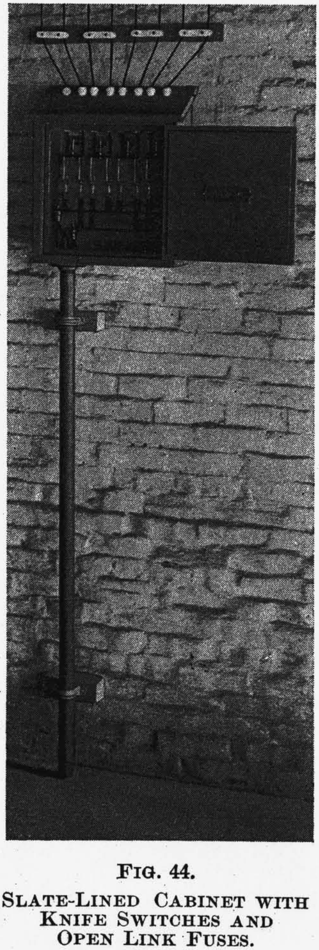


FIG. 44.

SLATE-LINED CABINET WITH KNIFE SWITCHES AND OPEN LINK FUSES.

Figs. 43 and 44, as well as Fig. 38, page 71, are excellent examples of thoroughly good cabinets of simple construction.

In all these illustrations, attention is called to the slanting top, which prevents the accumulation of dust upon it and keeps it from being used as a shelf. This is a very desirable feature. The bushings should be of such

54. **Cut-Out Cabinets** — *Continued.*

a length that they will reach just inside the cabinet, as longer ones are likely to become broken, and shorter ones do not afford sufficient protection.

Fig. 44, page 109, shows a wooden box lined with slate throughout, including the inside of the door, and containing link fuses and knife switches mounted on the slate back. The bus-bars are carefully taped and then painted with a black enamel paint, presenting a very neat appearance and greatly reducing the amount of bare live metal. The pipe which protects the feed wires is fastened to the bottom of the box by an ordinary pipe-flange, and each wire is separately encased in flexible insulating tubing.

In Fig. 43, page 109, plug type cut-outs and snap switches are used, making a fireproof lining unnecessary, and the box is merely painted thoroughly, inside and outside, with a good lead paint. The snap switches have a rated capacity of 30 amperes each, and are provided with indicating dials. In this instance the switches are mounted on a specially grooved slate block, but porcelain sub-bases can be obtained for most sizes and would be cheaper and more convenient. The glass door prevents shrinking, — a fault commonly found with doors made entirely of wood. It also keeps the apparatus always in sight, and the position of each switch can be seen without opening the door.

The cut also shows how current may be taken from risers running from floor to floor, the wires on the side walls being protected in iron pipe to a height of about 5 feet.

A cabinet of this character is inexpensive and thoroughly satisfactory, and it is heartily recommended as an example to be followed. With the enclosed fuses and snap switches, there is very little exposed live metal on which accidental short-circuits can be made, and this is of no little importance throughout the workrooms of a mill, where inexperienced persons are likely to turn the lights on and off.

54 A. Rosettes.

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 ¼ 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 ½ 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 ½ inch.

Bases for the moulding and conduit box types must be high enough to keep the wires and terminals at least ⅜ 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

54 A. **Rosettes** — *Continued.*

be countersunk not less than 1/8 inch and covered with a waterproof compound which will not melt below 150° Fahr.

c. **Terminals.** — Line terminal plates must be at least .07 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, and the terminal screws must not be smaller than No. 5 standard screw with about 40 threads per inch.

d. **Cord Inlet.** — The diameter of the cord inlet hole should measure 13/32 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. **Markings.** — 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 1 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 spring clip enclosed fuses are much preferable to the link-fused rosettes.

55. **Sockets.**

(*For installation requirements, see Rule 27, page 78.*)

Sockets of all kinds, including wall receptacles, must be constructed in accordance with the following specifications.

a. **Standard Sizes.** — The standard lamp socket must be suitable for use on any voltage not exceeding 250 and with any size lamp up to 50 c. p. For lamps larger than 50 c. p. a standard keyless socket may be used, or if a key is required, a special socket designed for the current to be used must be made. Any special sockets must follow the general spirit of these specifications.

55. **Sockets** — *Continued.*

b. **Marking.** — The standard socket must be plainly marked 250 v., 50 c. p., and with the manufacturer's name or registered trade-mark. Special sockets must be marked with the current and voltage for which they are designed.

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 .013 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 socket should start from their position under the binding screws.

The material used for lining must be at least $\frac{1}{32}$ 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.

e. **Cap.** — Caps, when of sheet brass, must be at least .013 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 $\frac{1}{8}$ 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 § *d* will provide a sufficiently smooth and well insulated surface for the knot to bear upon.

Sockets with an outlet threaded for $\frac{3}{8}$ 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 Rule 28 *d*, page 79.

f. **Frame and Screws.** — The frame which holds the moving parts must be sufficiently heavy to give ample strength and stiffness.

Brass pieces containing screw threads must be at least .06 inch in thickness.

55. **Sockets** — *Continued.*

Binding post screws must not be smaller than No. 5 standard screw with about 40 threads per inch.

g. **Spacing.** — Points of opposite polarity must everywhere be kept not less than 3/64 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. A turned-up 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.** — With the exception of the lining, all parts of insulating material inside the shell must be made of porcelain.

k. **Key.** — The socket key-handle must be of such a material that it will not soften from the heat of a 50 c. p. lamp hanging downwards from the socket in air at 70° Fahr., 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° Fahr.

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 the rate of about 2 or 3 times per minute, while carrying a load of 1 ampere at 250 volts, must "make and break" the circuit 6000 times before failing.

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.

55. **Sockets** — *Continued.*

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 9/32 inch in diameter. The edges of the bushing must be rounded 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 3/8 inch pipe should have a hole 13/32 inch in diameter, so that they will accommodate *approved* reinforced flexible cord.

56. Hanger-Boards.

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 non-combustible, non-absorptive insulating material. All switches attached to the same must be so constructed that they will 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.

If the switch opened only one side of the circuit and that side should happen to be grounded, there would be danger in handling the lamp.

57. Arc Lamps.

(*For installation requirements, see Rules 19 and 29, pages 62 and 80.*)

a. Must be provided with reliable stops to prevent the carbons from falling out in case the clamps become loose.

b. All exposed parts must be carefully insulated from the circuit.

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, if placed anywhere except on the lamp itself, must comply with the requirements for switches on hanger-boards as given in Rule 56.

The hand switch is needed, in order to entirely disconnect the lamp for the purpose of adjustment or trimming, while the automatic switch is to maintain the continuity of the circuit if it should be broken at the arc by any cause, such as failure of the regulating mechanism to feed the carbons properly.

58. Spark Arresters.

(*See Rules 19 c and 29 c, pages 62 and 81.*)

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.

59. Insulating Joints.

(*See Rule 26 a, page 77.*)

a. Must be entirely made of material that will resist the action of illuminating gases, and will not give way or soften

59. **Insulating Joints** — *Continued.*

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 5 minutes the application of an electro-motive force of 4000 volts; must be sufficiently strong to resist the strain to which they are liable to be subjected during installation.

b. Insulating joints having soft rubber in their construction will not be approved.

Because soft rubber soon hardens and cracks.

60. Rheostats.

(*For installation requirements, see Rules 4 a and 8 c, pages 28 and 34.*)

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.

Resistance boxes are used for the express purpose of opposing the passage of current, and are therefore very liable to get exceedingly hot. Hence they should have no combustible material in their construction.

b. **Construction.** — Must have legs which will keep the current-carrying parts at least 1 inch from the surface on which the rheostat is mounted.

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 ensure a thoroughly good connection, and must be sufficiently strong and heavy to withstand considerable hard usage. For currents above 30 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.

See also Rule 14 *c*, page 55, regarding soldering of wires at terminal connections.

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 towards 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

60. **Rheostats** — *Continued.*

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, an 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.

f. **No-voltage release.**— Motor-starting rheostats must be so designed that the contact arm cannot be left on intermediate segments, and 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.

g. **Overload-release.**— Overload-release devices which are inoperative during the process of starting the motor will not be approved, unless other circuit-breakers or fuses are installed in connection with them.

If, for instance, the overload-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. Regulators 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.

61. Reactive Coils and Condensers.

a. Reactive coils must be made of non-combustible material, mounted on non-combustible bases and must be treated, in general, as sources of heat.

This rule is not intended to apply to lightning arrester choke coils and similar apparatus in the construction of which non-combustible insulation is not practicable. These should, however, be mounted on non-combustible bases, the same as the other forms of reactive coils, etc.

Under some conditions reactive coils may get very hot, so that they should be treated about the same as rheostats, although the danger of extreme overheating is perhaps not as great.

b. Condensers must be treated like other apparatus operating with equivalent voltage and current. They must have non-combustible cases and supports, and must be isolated from all combustible materials and, in general, treated as sources of heat.

61. **Reactive Coils and Condensers** — *Continued.*

Condensers, like transformers, are practically harmless until some fault occurs in them. Then a short circuit occurs instantly, backed up by the full capacity of the wires, and continues until the automatic cut-outs open the circuit.

62. Transformers.

(For installation requirements, see Rules 11, 13, 13A and 36, pages 39, 50, 52 and 84.)

a. Must not be placed in any but metallic or other non-combustible cases.

On account of the possible dangers from burn-outs in the coils. (See note under Rule 11 *a*, page 39.)

It is advised that every transformer 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 constructed to comply with the following tests: —

1st. Shall be run for 8 consecutive hours at full load in watts under conditions of service, and at the end of that time the rise in temperature, as measured by the increase of resistance of the primary coil, shall not exceed 135° Fahr.

2d. The insulation of transformers when heated shall withstand continuously for 5 minutes a difference of potential of 10,000 volts (alternating) between the primary and secondary coils, and between the primary coils and the core. It must also stand a no-load "run" at double voltage for 30 minutes.

The 2d test above specified does not apply to transformers of rated primary voltage above 5000. For transformers designed for higher primary voltages, say, 5000 to 75000, the testing voltage should be substantially twice the rated voltage.

63. Lightning Arresters.

(For installation requirements, see Rule 5, page 29.)

a. Must be mounted on non-combustible bases; must be so constructed as not to maintain an arc after the discharge has passed; and must have no moving parts.

Whenever lightning is discharged through an arrester, the dynamo current tends to follow the discharge current, as the heat of the latter volatilizes a little of the metal and forms between the points a bridge of metal vapor, which quite readily conducts electricity. The arrester must be so designed as to break this arc, as otherwise the dynamos may be injured and the service interrupted. The arrester itself would also probably be injured, and might not then afford protection against a second discharge.

Moving parts are apt to become corroded and stuck, thus rendering the arrester inoperative.

CLASS E.

MISCELLANEOUS.

64. **Signaling Systems.** — *Governing wiring for telephone, telegraph, district messenger and call-bell circuits, fire and burglar alarms, and all similar systems.*

a. Outside wires should be run in underground ducts or strung on poles, and as far as possible should be kept off of buildings. They must not be placed on the same cross-arm with electric light or power wires, and should not occupy the same duct, manhole, or handhole of conduit systems with such wires.

Single manholes or handholes may be separated into sections by means of partitions of brick or tile, so as to be considered as conforming with the above rule.

b. When outside wires are run on same pole with electric light or power wires, the distance between the two inside pins on each cross-arm must not be less than 26 inches.

This distance between the inside pins is necessary to allow a man to safely pass between the wires and reach the cross-arms above.

c. All aërial conductors, and underground conductors which are directly connected to aërial wires, must be provided with some approved protective device, which must be located as near as possible to the point where they enter the building and not less than 6 inches from curtains or other inflammable material.

d. If the protector is placed inside of the building, the wires from the outside support to the binding posts of the protector must comply with the following requirements: —

1st. Must be of copper, and not smaller than No. 18 B. & S. gage.

2d. Must have an *approved* rubber insulating covering. (See Rule 41, page 86.)

3d. Must have a drip loop in each wire, immediately outside the building.

See Rule 12 *g*, page 42.

4th. Must enter buildings through separate holes, sloping upward from the outside, and when practicable, the holes should be bushed with non-combustible, non-absorptive, insulating tubes extending through their entire length. Where tubing is not practicable, the wires must be wrapped with two layers of insulating tape.

See Rule 12 *g*, page 42.

5th. Must be so supported on porcelain insulators that

64. **Signaling Systems** — *Continued.*

they will not come in contact with anything other than their designed supports.

6th. A separation between wires of at least 2½ inches must be maintained.

In case of crosses these wires may become a part of a high-voltage circuit, so that care similar to that given high-voltage circuits is needed in placing them. Porcelain bushings at the entrance holes are desirable, and this requirement is only waived under adverse conditions because the state of the art in this type of wiring makes an absolute requirement inadvisable.

e. The ground wire of the protective device must be run in accordance with the following requirements: —

1st. Must be of copper, and must not be smaller than No. 18 B. & S. gage.

2d. Must have an *approved* rubber insulating covering. (See Rule 41, page 86.)

3d. Must run in as straight a line as possible to a good permanent ground, to be made by connecting to water or gas pipe, — preferably water pipe. If gas pipe is used, the connection must in all cases be made between the meter and service pipes. In the absence of any other good ground, connection must be made to a metallic plate or bunch of wires buried in permanently moist earth.

In attaching a ground wire to a pipe, it is often difficult to make a thoroughly reliable soldered joint. It is better, therefore, where possible, to carefully solder the wire to a brass plug, which may then be firmly screwed into a pipe fitting. Where such joints are made underground, they should be thoroughly painted and taped to prevent corrosion.

One of the methods of making a "ground" shown in Figs. 11 and 12, pages 30 and 31, might be used where pipes are not available.

f. The protector must comply with the following requirements: —

1st. Must be mounted on a non-combustible, non-absorptive, insulating base, 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.

2d. 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 wires 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 instrument which the protector is guarding.

Heat coils are necessary in all circuits normally closed through magnet windings which cannot carry indefinitely a current of at least 5 amperes.

64. Signaling Systems — *Continued.*

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. These smaller currents are often called "sneak" currents.

The lightning arrester, fuses and heat coils should be mounted on the same base, so that the protector as a whole shall be self-contained.

3d. 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."

g. Wires beyond the protector, except where bunched, must be neatly arranged and securely fastened in place in some convenient and workmanlike manner. They must not come nearer than 6 inches to any electric light or power wire in the building, unless encased in *approved* tubing so secured as to prevent its slipping out of place

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.

h. Wires connected with outside circuits, where bunched together within any building, or inside wires laid in the same conduits or ducts with electric light or power wires, must have fire-resisting coverings, or else must be enclsoed in an air-tight tube or duct.

It is feared that if a burnable insulation were used, a chance spark might ignite it and cause a serious fire, for many insulations contain a large amount of very readily burnable matter.

See note under Rule 2 *b*, page 25.

64 A. Additional Rules for Factory Mutual Work.

In this work, the following rules, which are additional to the "Code," must be carefully followed, as the more or less isolated location of the majority of factory properties makes it possible to introduce some very desirable requirements not universally feasible.

a. Foreign wires (*i. e.*, those not owned or controlled by the insured, such as any public light or power wires, public telephone, telegraph, and city fire-alarm wires, etc.) of all kinds, not used by the insured, should be kept off of all buildings, and out of the yards of properties insured by these companies.

Foreign signal wires, such as telephone, telegraph, etc., with their generally long circuits and often careless line construction, are especially liable to come in contact with light and power wires. If they are attached to mill buildings or allowed to cross mill yards, there is always the danger that they will break and come in contact with some private mill wire, sending a dangerous current into the buildings, and thereby probably causing a fire. Foreign light and power wires are excluded for similar reasons. Such wires, moreover, are liable to be in the way of fire-streams and ladders.

Under this heading would also come trolley wire supports, which are not desirable on buildings, as they tend to conduct lightning to the building and also may not always be thoroughly insulated from the live trolley wire.

64 A. **Additional Rules for Factory Mutual Work** — *Continued.*

b. All wires used by the insured should be systematically laid out through the yards. Special care should be taken to so locate them that they will not interfere with fire-streams or ladders.

This matter is ordinarily given too little attention, with the result that an unsightly tangle of wires eventually results, inviting crosses which may conduct dangerous currents into the buildings, and often so located as to obstruct fire-streams and hinder the putting up of ladders. In general, wires should approach buildings as nearly at right angles as possible, and where they are run parallel to the buildings, they should be kept at least 50 feet away from them if possible.

c. Private wires (*i. e.*, those owned and controlled by the insured, such as watch-clock, private telephone, call-bell and similar wires) must be arranged about as follows: —

1st. Where possible, run them so that they cannot fall or be fallen upon by any wire carrying a dangerous current or likely to come in contact with a wire carrying a dangerous current.

2d. Where crosses cannot be prevented, provide guard wires that will absolutely prevent contacts.

3d. Where crosses must occur, and guard wires cannot be arranged, provide protectors as required by Rule 64, page 118.

It will generally be found possible in arranging private wires about the mill yards to so keep them by themselves that there will be no possibility of their coming in contact with circuits carrying dangerous currents. Such avoidance of the possibility of danger is always preferable to the putting in of protectors, besides being generally less expensive.

65. **Electric Gas Lighting.**

a. Electric gas lighting must not be used on the same fixture with the electric light.

65 A. **Moving Picture Machines.**

a. The top reel must be encased in an iron box with a hole at the bottom only large enough for the film to pass through, and the cover must be so arranged that this hole can be instantly closed. No solder shall be used in the construction of this box.

b. A box must be used for receiving the film after being shown, made of galvanized iron with a hole in the top only large enough for the film to pass through freely, with a cover so arranged that this hole can be instantly closed. An opening may be placed at the side of the box to take the film out, with a door hung at the top, so arranged that it cannot be entirely opened, and provided with a spring catch to lock it closed. No solder shall be used in the construction of this box.

c. The handle or crank used in operating the machine must be secured to the spindle or shaft, so that there will be no liability of its coming off and allowing the film to stop in front of the lamp.

65 A. **Moving Picture Machines** — *Continued.*

d. A shutter must be placed in front of the condenser, arranged so as to be normally closed, and held open by pressure of the foot.

e. A metal pan must be placed under the arc lamp to catch all sparks.

f. Extra films must be kept in metal boxes with tight-fitting covers.

66. Insulation Resistance.

a. 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 less than that given in the following table: —

Up to	5 amperes	4,000,000 ohms.
"	10 "	2,000,000 "
"	25 "	800,000 "
"	50 "	400,000 "
"	100 "	200,000 "
"	200 "	100,000 "
"	400 "	50,000 "
"	800 "	25,000 "
"	1,600 "	12,500 "

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.

67. Soldering Fluid.

a. The following formula for soldering fluid is suggested:

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

APPENDIX.

GROUND DETECTORS.

With the exception of intentionally grounded neutral wires, it is always important to keep the wires of any electric light or power system absolutely free from contacts with anything which could connect them to the earth, such as walls or floors of masonry, iron beams, etc., and, above all, iron pipes of any kind. This is accomplished in ordinary mill work, first, by the porcelain knobs or cleats on which the wires are supported, and next, by the insulation on the wires themselves. Wires do sometimes get out of place, however, and come in contact with damp walls, sprinkler pipes, etc., and then in time the insulation on the wire wears through, helped by the jar of the building, and the copper itself comes in contact with the wall, pipe, etc., thus putting the wire into electrical connection with the earth. Nothing will usually happen, however, until a wire of opposite polarity also becomes "grounded," for until then there is no complete circuit made. When this does occur, the current follows through the earth or pipes from one "ground" to the other, forming arcs at these points, and perhaps elsewhere, and these arcs are very liable to cause fire.

The purpose of the ground detector is to give a warning when the first break in insulation occurs, thereby giving time to repair it before the second one, with its possible accompanying fire, can follow.

The instant a detector shows a ground, steps should be taken to find and remedy it. By throwing off one circuit after another, the one on which the ground exists will soon be found, as when it is cut off the detector lamps will again burn with equal brilliancy. Inspection along this circuit will then generally soon disclose the trouble. Where the circuits are not well sub-divided by switches, fuses may be removed to accomplish the same result.

DIRECT-CURRENT CIRCUITS.

Fig. 45 on page 124 shows a very good and simple detector for any two-wire low-voltage system. The lamps for the detector should be of the same candle power and voltage,—the voltage being about the same as that of the regular lamps in the plant,—and two lamps should be selected which, when connected in series, burn with equal brilliancy. Although somewhat greater sensitiveness can be obtained with low candle-power lamps, such as 8 c.p., for example, it is believed in general to be preferable to use lamps of same candle-power as those throughout the plant, as then a burned-out or broken detector lamp can be immediately replaced by a good lamp from the regular stock, thus avoiding the necessity of keeping on hand a few spare special lamps.

The detector lamps, being two in series across the proper voltage for one lamp, burn only dimly. If, however, a ground occurs on any circuit, as at *a*, the current from the positive bus-bar through lamp No. 1 divides on reaching *b*, instead of all going through lamp No. 2, as it did when there was no ground. Part now goes down the ground wire and through the ground to *a*, as indicated by the broken line, and thence through the wires to the negative bus-bar. This reduces the resistance from *b* to the negative bus-bar, and therefore more current flows through lamp No. 1 than before, while less current flows through lamp No. 2. Lamp No. 1 consequently brightens and lamp No. 2 dims. If the ground had occurred at *c* instead of *a*, lamp No. 2 would have brightened and lamp No. 1 dimmed.

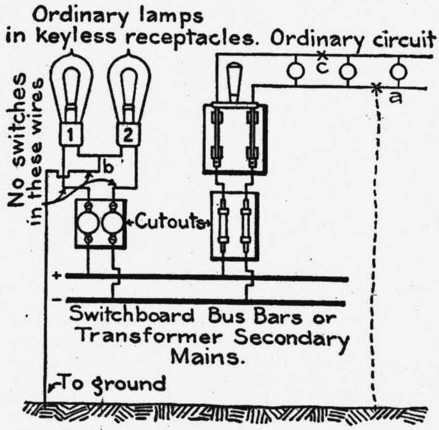


Fig. 45.

Two-Lamp Ground Detector.

Attention is called to the following points, which are frequently neglected in this form of detector: —

1. The lamp receptacles should be keyless and there should be no switches of any kind in any of the connecting wires, so that the detector will always be in operation. In order to be of the greatest value, the indications must be given instantly when a ground occurs, and not have to wait until the engineer or electrician remembers to close a switch.

2. The wires should be protected by small fuses where they connect to the bus-bars. If these fuses are omitted, a short-circuit across these wires would either burn up the wires or blow the main generator fuses.

3. The lamps should be placed very close together, within 1 or 2 inches of each other if possible. The farther apart they are, the harder it is to detect any slight difference in brilliancy between them.

4. The ground wire should be carefully soldered to a pipe which is thoroughly connected to the ground, or some other equally good ground connection should be provided.

In some laboratory tests of a two-lamp detector made with two ordinary 110 volt, 16 c. p. lamps, the following sensitiveness was found.

Difference in Brightness of Lamps.	Insulation Resistance. Ohms.
Just noticeable in rather dark place	2700
Easily detected	1700
One lamp red, other bright	500

This shows that the detector, while not able to indicate extremely small leaks, will show any leak that is likely to be dangerous from a fire standpoint.

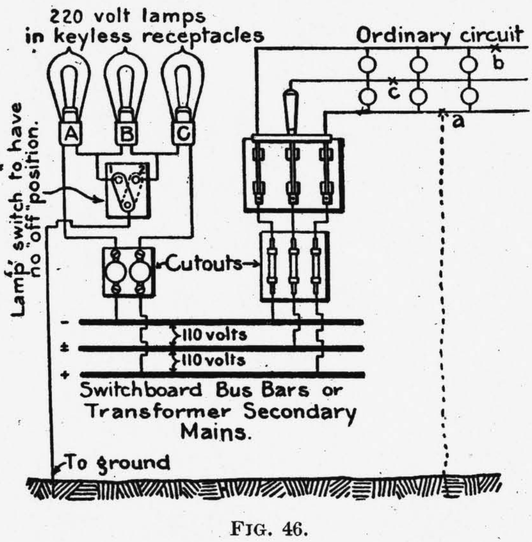


Fig. 46.

Lamp Ground Detector for Three-Wire System.

Fig. 46 shows a lamp ground detector for a three-wire Edison system. In principle it is exactly the same as the two-lamp detector of Fig. 45. Its indications are as follows : —

Switch on point No. 1.	Ground at *a*, —	A	bright,	B & C dim.
	" " *b*, —	B & C	"	A "
	" " *c*, —	A	"	B & C "
Switch on point No. 2.	Ground at *a*, —	A & B	bright,	C dim.
	" " *b*, —	C	"	A & B "
	" " *c*, —	C	"	A & B "

With the lamp switch at point No. 1, grounds at *a* and *c* give the same indication, but by throwing the switch to point No. 2, it will be at once evident whether the ground is on the positive or the negative side. It is to remove the uncertainty which would otherwise exist that this switch is needed.

It should have no "off" position, so that the detector can never be left out of circuit.

The man in charge of a plant can readily familiarize himself with the indications of the detector by purposely putting a ground on the different wires and noting the indications.

If the neutral is permanently grounded, as permitted in Rule 13 A, page 52, a ground detector is, of course, of no use.

The following table shows the sensitiveness obtained in some laboratory tests, using ordinary 220 volt, 16 c. p. lamps.

Difference in Brightness of Lamps.	Insulation Resistance, Ohms. Positive.	Negative.	Neutral.
Just noticeable in rather dark place	18800	8900	3700
Easily detected	9000	6500	2600
One or two lamps dull red, others bright	3800	3300	500
One or two lamps faint red, others bright	2400	1400	0
One or two lamps just out, others bright	1200	700	0

The same degree of sensitiveness on both sides can be obtained by means of the lamp switch, but for grounds on the neutral, there is never more than half the full voltage available to operate the lamps, so that the indications are necessarily less sensitive.

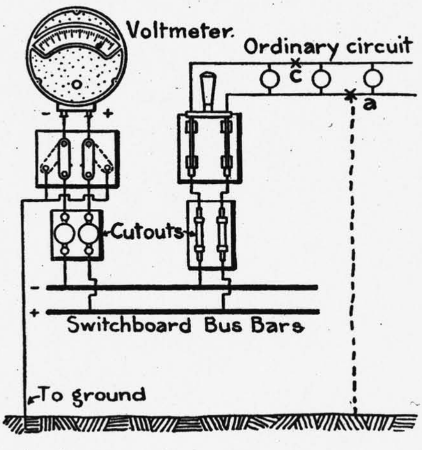


FIG. 47.
VOLTMETER GROUND DETECTOR.

An ordinary voltmeter can be used as an intermittent ground detector on direct-current circuits of any voltage, the method being as shown in Fig. 47. The voltmeter ordinarily used to indicate the pressure on the system, can, of course, be used for this purpose, the voltmeter switch shown in the cut being arranged to give the different desired connections.

If, for example, the system shown in Fig. 47 was of about 100 volts, the voltmeter would register 100 when the levers of the switch were on the inside contact points as shown. If, now, the right-hand lever was moved to the outside contact point as shown dotted, and there was a ground on the system, as at *a*, current would pass from the positive bus-bar through the circuit to *a*, thence through the ground to the ground wire, and through the voltmeter to the negative bus-bar, causing the voltmeter to read something below 100, unless the ground at *a* was practically a perfect connection, in which case the voltmeter reading would be 100. If the positive side of the system was entirely free from grounds, the voltmeter reading would be 0.

Assume that under these conditions the voltmeter read 50, and that the resistance of the voltmeter itself was 20,000 ohms, it will be evident that if, with no external resistances, as when connected directly to the bus-bars, the voltmeter read 100, while now it reads 50, the total resistance under the new conditions must be 40,000 ohms, of which $40{,}000 - 20{,}000 = 20{,}000$ ohms must be the resistance of the ground at *a*.

If the voltmeter had read only 20 the total resistance would have been $\frac{100}{20} \times 20{,}000 = 100{,}000$, and the resistance of the ground $100{,}000 - 20{,}000 = 80{,}000$ ohms.

A table may, therefore, be computed in this way showing the resistance of the ground for any given reading of the voltmeter. It is a good plan in any low-voltage system to connect the voltmeter in this way, besides having a lamp ground detector, as the voltmeter gives a more exact idea of just what the insulation is, while the lamp detector gives an instantaneous indication of a ground and is not dependent on the attendant remembering to throw it in, as is the case with the voltmeter.

A special ground-detecting voltmeter designed for continuous operation and arranged with a pointer moving on each side of a zero point, so that a ground on either side of the system will be automatically shown, can be obtained. Such a detector makes the best instrument for all direct-current work where the voltage is too high for the use of any form of lamp detector, as, for instance, on series arc light circuits. This special instrument is better than an ordinary voltmeter arranged as in Fig. 47, as it can be kept in circuit all the time, thus being entirely automatic in its action.

Where none of the above-mentioned methods are available, fair results can be obtained by frequent tests with a powerful magneto while the current is cut off from the system.

ALTERNATING-CURRENT CIRCUITS.

For all ordinary low-voltage single-phase systems, the lamp detectors above described can be used with good results.

For ordinary low-voltage three-phase circuits, a lamp detector connected as in Fig. 48, page 128, may be used. The indication is the same as that with the lamp detectors described above. Thus, when a ground comes on one wire, the lamp attached to that wire dims and the other two brighten.

For ordinary two-phase (or quarter-phase) systems, where the phases are entirely insulated from each other, the two-lamp detector can be used, one detector on each phase. There are, however, in this class of wiring several complicated systems, to all of which the lamp detector principle is applicable, although the exact method of connections differs in each case, so that no general rule can be given.

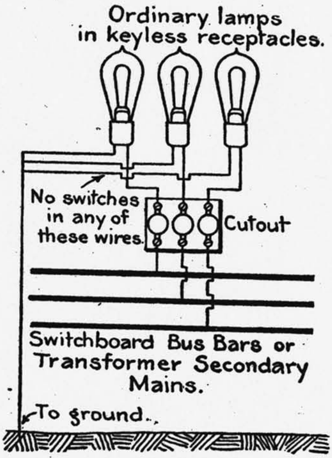


FIG. 48.
THREE-PHASE LAMP DETECTOR.

With alternating-current systems where the voltage is too high for the methods suggested above, excellent results can be obtained where direct current is available by testing the line with a direct-current voltmeter, as in Fig. 47, page 126. This can only be done, of course, while the high-voltage current is cut off. If there is no direct current at hand, the line may be frequently tested out with a powerful testing magneto when the current is off the system. With extra high voltages, there is usually either no ground or else a fairly good one, so that either of these two methods can be used to advantage.

There are also a few instruments on the market especially designed for this work, such as the electrostatic detector, in which the difference of static charge on adjacent segments moves a pivoted vane, to which is attached an indicating needle moving over a dial. There is also the "transformer and lamp" detector, in which a small transformer is used with an incandescent lamp in the secondary circuit. One of the primary wires is connected with the ground, and by means of switches suitably arranged, the other primary is connected to any wire of the system, a ground being indicated by the burning of the lamp. The indications of this instrument are misleading, except to those thoroughly acquainted with its operation under all conditions.

GENERAL WIRING FORMULÆ.

$$V = \frac{D \times W \times R \times B}{E \times A}, \text{ or } V = \frac{L \times E \times B}{100}$$

$$A = \frac{D \times W \times R \times B}{E \times V}, \text{ or } A = \frac{D \times W \times R \times 100}{L \times E^2}$$

$$C = \frac{W \times T}{E}$$

$$L = \frac{D \times W \times R \times 100}{E^2 \times A}$$

$$P = \frac{D^2 \times W \times R \times S}{L \times E^2 \times 10{,}000}, \text{ or } P = \frac{D \times S \times A}{1{,}000{,}000}.$$

V = Volts drop in line.
D = Distance, in feet, between the two points, along the wires.
W = Total power *delivered*, in watts.
E = Voltage at *receiving* end of line.
A = Area of cross-section of wire, in circular mils.

The area in circular mils of B. & S. gage sizes from No. 10 to No. 0000 inclusive will be found in the table on page 101. For wires smaller than these, see table on page 39.

C = Current in each wire, in amperes.
L = Loss in line, in per cent. of W.
P = Total pounds of copper in line.
R = A constant, for value of which see table on page 101.
S = " " " " " "
T = " " " " " "
B = " " " " " "

For direct-current systems, $R = 21.6$, $B = 1.00$, $T = 1.00$, and $W = C \times E$, so that the first two of the above formulæ reduce to $V = \frac{D \times C \times 21.6}{A}$, and $A = \frac{D \times C \times 21.6}{V}$.

In a balanced three-wire, two-phase, alternating-current system, the current in the middle wire is 1.41 times that in each outside wire, the current in the outside wires being computed from the formula as if the system was a four-wire one.

When the power factor cannot be accurately determined, it may be assumed to be as follows for any alternating-current system operating under average conditions: lighting, with no motors, 95%; lighting and motors, 85%; motors only, 80.%

The values of B are for wires 18 inches apart, centre to centre, and are sufficiently accurate for all practical purposes, provided that the reactance of the line is not excessive or the line loss unusually high. They represent the true values at 10% line loss; are close enough for all losses less than 10%; and are often close enough for losses considerably above 10% —

at least for frequencies up to 40 cycles. Where the conductors of a circuit are less than 18 inches apart, the value of B is less than that given in the table, and if they are close together, as with multiple conductor cable, B becomes equal to unity and can be omitted from the formulæ.

The following examples are given to show how the different formulæ are to be applied :—

1. What size wire is needed to transmit current 200 feet to a centre of distribution for 60 incandescent lamps on a 110 volt direct-current system, with a drop of 3%, which is an actual drop of 3.3 volts?

The table on page 59 shows that a 16 c. p. lamp at 110 volts takes .52 ampere, so 60 lamps would take 31.2 amperes.

Hence D = 200, C = 31.2, and V = 3.3, from which, using the simplified formula for direct-current, we have

$$A = \frac{200 \times 31.2 \times 21.6}{3.3} = 40840.$$

From the table on page 131, we see that the nearest B. & S. gage size above this is No. 4, which is the proper size to use.

2. What is the current in each wire of a three-phase circuit feeding two motors developing 20 H. P. each, the voltage at the motors being 550?

40 H. P. = 40 × 746 watts = 29840 watts. Assuming a power-factor of 85% (see note on page 129), we find from the table that the value of T for this power-factor on a three-phase, three-wire system is .68. Then from the formula, we have

$$C = \frac{29840 \times .68}{550} = 36.9 \text{ amperes.}$$

3. In a two-phase, 60 cycle transmission line, with four No. 2 B. & S. gage wires 18 inches apart, supplying lighting transformers at a point 1⅝ miles from the generating station, what must be the voltage at the generator switchboard to give a voltage of 2080 at the transformers when the load on the transformers is 188 K. W.?

1⅝ miles = 8580 feet, and 188 K. W. = 188000 watts. Hence D = 8580, W = 188000, E = 2080; and from the table R = 12.00, A = 66600, and B = 1.18, assuming a power factor of 95% (see notes on page 129).

Inserting these values in the formulæ for L and V, we have

$$L = \frac{8580 \times 188000 \times 12 \times 100}{(2080)^2 \times 66600} = 6.72 \text{ and}$$

$$V = \frac{6.72 \times 2080 \times 1.18}{100} = 165 \text{ volts.}$$

Therefore the voltage at the generator must be 2080 + 165 = 2245.

SYSTEM	VALUES OF S.	VALUES OF R. PER CENT. POWER FACTOR. 100	95	90	85	80	VALUES OF T. PER CENT. POWER FACTOR 100	95	90	85	80
Single-phase	6.04	21.60	24.00	26.60	30.00	33.80	1.00	1.05	1.11	1.17	1.25
Two-phase (four-wire)	12.08	10.80	12.00	13.30	15.00	16.90	.50	.53	.55	.59	.62
Three-phase (three-wire)	9.06	10.80	12.00	13.30	15.00	16.90	.58	.61	.64	.68	.72

VALUES OF B (for wires 18 inches apart).

No. of Wire, B. & S. Gage.	Area Wire, Circular Mils.	Weight of Bare Wire per 1000 feet, Pounds.	Resistance of Wire per 1000 feet at 25° C., Ohms.	25 CYCLES. PER CENT. POWER FACTOR. 95	90	85	80	40 CYCLES. PER CENT. POWER FACTOR. 95	90	85	80	60 CYCLES. PER CENT. POWER FACTOR. 95	90	85	80	125 CYCLES. PER CENT. POWER FACTOR. 95	90	85	80	No. of Wire, B. & S. Gage.
0000	212000	641	.0499	1.23	1.29	1.33	1.34	1.52	1.53	1.61	1.67	1.62	1.84	1.99	2.09	2.35	2.86	3.24	3.49	0000
000	168000	509	.0628	1.18	1.22	1.24	1.24	1.40	1.41	1.48	1.51	1.49	1.66	1.77	1.95	2.08	2.48	2.77	2.94	000
00	133000	403	.0794	1.14	1.16	1.16	1.16	1.25	1.32	1.35	1.37	1.34	1.52	1.60	1.66	1.86	2.18	2.40	2.57	00
0	106000	320	.0997	1.10	1.11	1.10	1.09	1.19	1.24	1.26	1.26	1.31	1.40	1.46	1.49	1.71	1.96	2.13	2.25	0
1	83500	253	.126	1.07	1.07	1.05	1.03	1.14	1.17	1.18	1.17	1.24	1.30	1.34	1.36	1.56	1.75	1.88	1.97	1
2	66600	202	.159	1.05	1.04	1.02	1.00	1.11	1.12	1.12	1.10	1.18	1.23	1.25	1.26	1.45	1.60	1.70	1.77	2
3	52400	159	.202	1.03	1.02	1.00	1.00	1.07	1.08	1.07	1.05	1.14	1.17	1.18	1.17	1.35	1.46	1.53	1.57	3
4	41600	126	.254	1.02	1.00	1.00	1.00	1.05	1.06	1.03	1.00	1.11	1.12	1.11	1.10	1.27	1.35	1.40	1.43	4
5	33100	100	.319	1.00	1.00	1.00	1.00	1.03	1.01	1.00	1.00	1.08	1.08	1.06	1.04	1.21	1.27	1.30	1.31	5
6	26200	79.5	.403	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.05	1.04	1.02	1.00	1.16	1.20	1.21	1.21	6
7	20700	62.8	.510	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.03	1.02	1.00	1.00	1.12	1.14	1.14	1.13	7
8	16600	50.4	.635	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.09	1.10	1.09	1.07	8
9	13000	39.4	.813	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.06	1.06	1.04	1.02	9
10	10400	31.5	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.04	1.03	1.00	1.00	10

INDEX TO RULES.

Number, Section and Page of Rule.

Number, Section and Page of Rule.

INDEX TO CUTS.

The Riverside Press
Electrotyped and printed by H. O. Houghton & Co.
Cambridge, Mass., U. S. A.