DISCUSSION
OF THE
NATIONAL ELECTRICAL SAFETY CODE

[To Accompany the Fourth Edition of the Code]

1928

HANDBOOK SERIES
OF THE
BUREAU OF STANDARDS

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DEPARTMENT OF COMMERCE

BUREAU OF STANDARDS

George K. Burgess, Director

HANDBOOK SERIES OF THE BUREAU OF STANDARDS, No. 4

DISCUSSION OF THE NATIONAL ELECTRICAL SAFETY CODE

(TO ACCOMPANY THE FOURTH EDITION OF THE CODE)

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PREFACE

Two previous editions of the National Electrical Safety Code have been accompanied by a discussion of the rules. In the second edition this discussion was included under one cover with the code. For the third edition it was published under a separate cover and this practice has been repeated for the fourth edition. The extensive rearrangement of the rules in the fourth edition of the code makes a new edition of the discussion seem advisable. The old material has been rearranged and, where necessary, modified to fit the revised text of the rules. New material has been introduced mainly to accompany new or altered rules.

The fourth edition of the National Electrical Safety Code has, like the third, been approved by the American Engineering Standards Committee as an American standard, although there has not yet been complete agreement among the various interests concerned, especially with reference to the crossing of overhead lines over railroad tracks. A joint committee has been arranged for by the American Railway Association and the National Electric Light Association to further consider crossing requirements and to see if agreement can not be reached regarding acceptable specifications for such situations. Meanwhile the provisions of the fourth edition should replace those of the third edition in those jurisdictions where the code rules have been in force.

The general discussion of line failures which has been involved in the development of the code rules has indicated that data are urgently needed regarding details of the line construction at the specific points where failures have occurred. A knowledge of the average construction of the line may still leave doubtful the inferences drawn from the failures in it.

To get line construction details at specific points of failure it seems generally necessary to have a previous record of the facts regarding the design of the line and its construction. In the hurry of restoring service after a line failure the details necessary to an engineering analysis are seldom recorded and the direct evidence is usually destroyed by the replacement of materials. Under these conditions a subsequent analysis of the adequacy of the line construction is accordingly inconclusive unless previously recorded data are available. Cooperation of railroad and other utility companies and of administrative officials concerned is invited in securing data of this nature.

It is realized that many questions involved in the rules are not fully covered by this discussion, and comments are invited from engineers familiar with the conditions under consideration.

George K. Burgess, *Director.*

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DISCUSSION OF THE NATIONAL ELECTRICAL SAFETY CODE

Section 9. RULES COVERING METHODS OF PROTECTIVE GROUNDING OF CIRCUITS, EQUIPMENT, AND LIGHTNING ARRESTERS FOR STATIONS, LINES, AND UTILIZATION EQUIPMENT [1]

Object of protective grounds.—The object of protective grounds on electric circuits or equipment, as required by the rules of this code, is to keep some point in the electric circuit or equipment at, or as near as practicable to, the potential of the earth in the vicinity, in order to prevent the passage of dangerous amounts of current through the bodies of persons in case of accidental contact with the live conductors or conducting material. Grounding may be accomplished by a metallic connection to a plate or pipe embedded in the soil or to conducting bodies in contact with it or extending into it, such as steel building frames, steel poles, water and gas pipes.

In case of an accidental contact or leakage between a utilization circuit and some other circuit of higher voltage, or between a grounded case and the circuit within, the ground connection may be called upon to discharge considerable current, and therefore its resistance must be low enough to prevent the potential of the utilization circuit or case from rising to a dangerously high value above that of the ground. The resistance of the ground connection limits this current flow; hence the effectiveness of a ground connection depends very largely upon its resistance, which should be made as small as

[1] A detailed discussion of ground connections will be found in B. S. Tech. Paper, No. 108, Ground Connections for Electrical Systems.

practicable. In general, the grounding of circuits or equipment as a protective measure should be carried out in such a manner that its effectiveness is reasonably assured at all times and so that no considerable hazard is introduced because of the type of ground used. The greatest degree of effectiveness, or, in other words, the lowest resistance attainable by practical methods, is necessary for adequate protection where ground connections may, in case of crosses or leakage, be required to carry large amounts of current. Furthermore, the passage of current through poor or high-resistance grounds may result in overheating and drying of the ground, with an accompanying increase of resistance and excessive potential difference, thus defeating the very object for which protective grounds are installed.

Summary of the rules.—Figure 1 gives in diagrammatic form a summary of the rules on grounding, including the circuits to be grounded, as given in rule 304.

90. Scope of the Rules.

It is the purpose of the rules of this section to specify the proper methods to be used in the grounding of electrical circuits and electrical equipment (transformer cases, switchboard frames, motor frames, conduit, etc.) when such grounding is required by other rules of the code. It is to be noted that not all circuits and equipment are required to be grounded. In the other sections of the code and particularly in rules 113 and 304 the circuits and equipment required to be grounded are specified.

Cases may occasionally arise where good judgment will dictate more elaborate precautions than the rules require in order that a reasonable degree of safety be assured.

91. Application of the Rules.

It is not expected that a set of rules or methods of procedure can be devised which will cover every individual case; hence the application of the rules is left in special cases to the

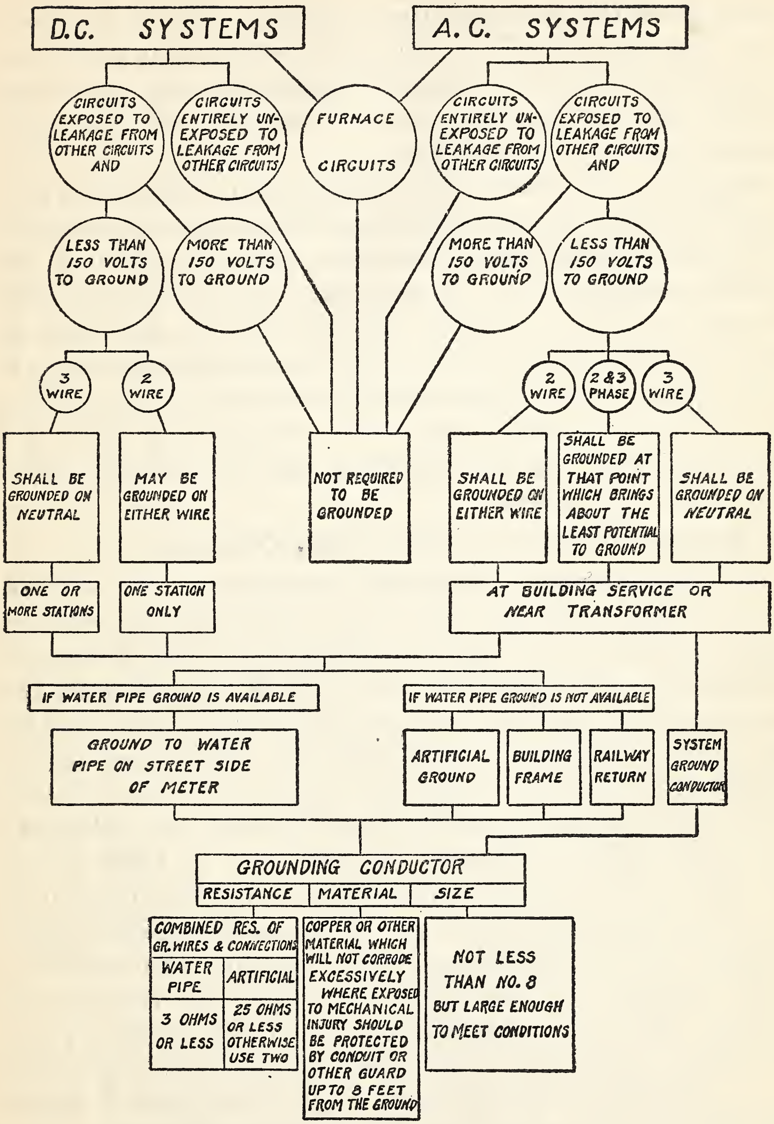

FIG. 1.—*Summary of rules for grounding circuits*

judgment of the administrative authority. In general, however, the rules should be adhered to wherever possible, because they represent the best that experience and experiment afford at the present time, and no departure should be made without mature consideration.

Departure from the exact requirements of the rules is permitted in temporary installations and some other cases where it is satisfactorily shown that equivalent protection is obtained by other means. In some cases the necessary expense involved would not warrant strict compliance, and alternatives approved by the administrative authority may be utilized. This applies to the method and details of grounding, but omission of grounding where required by the rules should never be tolerated without specific authority after thorough investigation.

92. Point of Attachment of Grounding Conductor.

(a) Direct-current distribution systems.—It is evident that the single ground connection permitted on two-wire direct-current circuits and the restricted number permitted on three-wire direct-current circuits do not provide quite the same assurance against loss of protection that is provided by the multiple grounds recommended for alternating-current distribution circuits. There are, however, a few factors which offset in large measure the apparently less adequate protection on direct-current circuits. One of these is the fact that such circuits are largely underground or confined to private premises, and hence are not so much exposed to high voltages as are alternating-current circuits. In addition, larger ground wires are usually installed, and they are at stations under expert supervision, which reduces the chance of breakage, while the benefits from reduction of the possibility of electrolytic damage which might occur were multiple grounds required or permitted are sufficient to warrant the restriction of the number of ground connections.

(b) **Alternating-current distribution systems.**—Ground connections at all building entrances served by any particular secondary circuit are desirable, since they permit ready means for inspection and testing and also, because of their number, provide good insurance against the entire loss of the ground connection. Moreover, the resistance of multiple grounds varies very nearly inversely as their number, so the greater the number the more readily automatic protective devices are opened in case of accident, and the greater the degree of safety provided.

Figure 2 illustrates the proper point of attachment for the grounding conductor of alternating-current circuits, as required by this rule.

Lighting circuits with their frequent use of small portable appliances generally present more difficulty and expense in grounding noncurrent-carrying metal parts and in guarding live parts (as on panel boards) than do motor circuits, so the provision of adequate protection is usually simpler if the lighting circuits are confined to a single phase (where a two or three phase system is used) and that phase is grounded, preferably at the neutral conductor, if there is one.

Where two or three phase systems are utilized for motors, the fixed character of such devices and their comparatively large size and infrequency render the guarding of thier live parts and the grounding of their frames (if called for by rules of Part 3 for the voltages concerned) a relatively simple and inexpensive matter.

If the distance from any point of a secondary grounded conductor to the nearest ground connection in either direction is very great, the size of the grounded conductor must be examined to ascertain whether it is sufficient to give the required conductance and current-carrying capacity.

If the secondary circuit loses its ground connection by the blowing of a fuse while the primary winding remains connected to the line a hazardous condition is created. To insure permanent continuity of the ground connection,

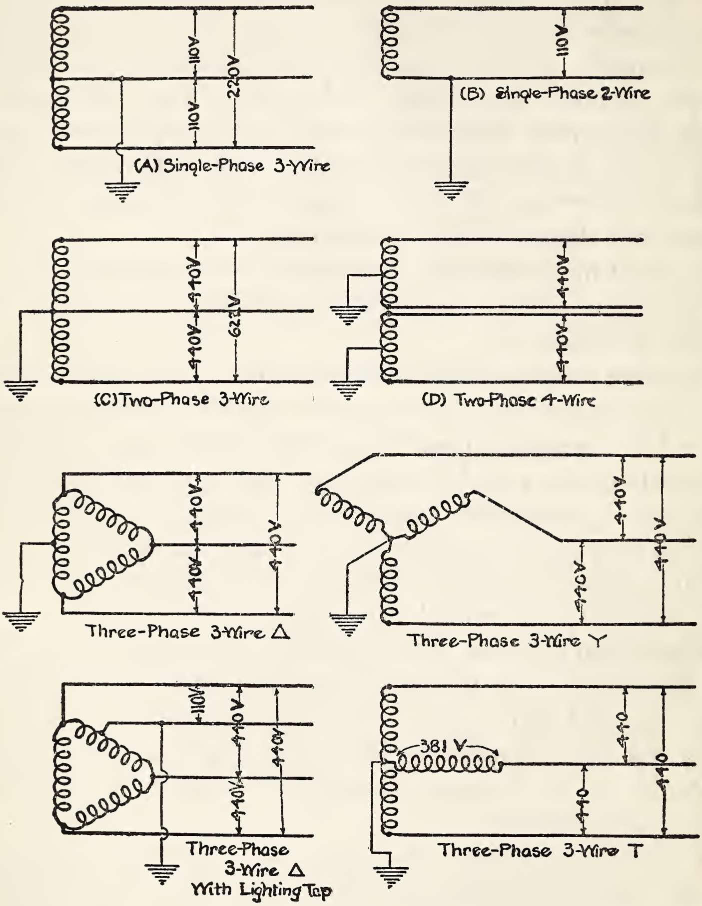

FIG. 2.—*Point of attachment of grounding conductor for alternating-current systems*

ground connections, and fuses should be so placed in relation to each other that the secondary winding is always connected to earth.

(c) **Current in grounding conductor.**—Where multiple grounds are used there is a possibility of circulating currents between the different ground connections, arising from unbalanced loads, improper connection of grounding wires, and for other reasons. It is advisable to ascertain the amount of this current flow when the grounds are made in order to make certain that it is not great enough to be objectionable. A fraction of an ampere, or even several amperes on circuits of large capacity, may not be a serious matter, but cases can easily arise where the flow would be sufficient to be disturbing to the service.

The advantages in permanency and reliability which result from the use of a number of grounds on a given circuit feeding a considerable area will generally warrant the use of multiple grounds on alternating-current secondaries, notwithstanding the possible existence of slight interchange of alternating current over these connections due to moderate unbalancing of the circuit, or to other causes, since heating or electrolysis from such small currents will be entirely negligible. A value of interchange current which would not be harmful with alternating current might, however, be sufficient to cause damage if on a direct-current system.

If the protective ground connection normally carries current, it is part of a closed circuit, and this may be an undesirable type of ground by reason of introducing other hazards. Direct current, in particular, may cause electrolytic damage, if not confined wholly to the metallic circuit and the utilization devices designed for use with the direct current. Multiple grounds from a neutral wire of a direct-current three-wire circuit may, if the direct-current circuit is unbalanced, cause earth currents and produce electrolytic damage by reason of such earth currents. Even alternating current, in large amounts or long continued, may unnecessarily deteriorate the ground connection, but such a current could only result from a fault or from excessive unbalancing of three-wire alternating-current circuits with multiple ground connections, and such unbalancing would soon be detected and corrected. With artificial grounds, the drying out of surrounding soil under such conditions might be serious, and with direct-current neutrals might result in destruction of the grounding wire by corrosion, the protection afforded by the artificial ground thus being lost.

An objectionable flow of current over a grounding conductor may be due to any one of several reasons, including the location of electric railway returns in close proximity to water pipes or other grounds,which carry part of the railway current through the supply conductors themselves from one ground connection to another. This might result in the deterioration and ultimate failure of such ground connections from electrolysis or drying out of the ground.

In this connection it might be well to consider cases in which the high-tension side of a distribution or station transformer is grounded. Where transformer banks consisting of three single transformers connected in star on the high-tension side have the neutral point grounded, a certain amount of current will flow in this ground connection because of the third-harmonic voltage present. This current may be of considerable value unless proper methods are employed to control it. Station transformer banks may also have their secondary windings connected in star and the neutral point grounded. In some cases the neutral wire may not be carried out of the station as the fourth wire of a three-phase system, as when the load supplied is almost exclusively a power load. In such systems, where lighting is supplied, a single-phase transformer is sometimes installed so that one side of its primary winding is connected to one of the phase wires and the other side to the ground. This results in a continual flow of current at all times, varying from the small excitation current under no-load conditions to a maximum at full load. If an artificial ground is used, this flow of current may result in a drying out of the soil so that in dry sections of the country the soil immediately adjacent to the artificial ground may become nonconducting. As a result the potential of the ground connection may be raised much above ground and even approach that of the line. It is evident that a very serious condition of hazard may be produced because the high voltage is brought down to the ground line. Should a rain occur at such time there is danger of the pole burning off because of current flow across the surface of the pole. This practice should, therefore, be avoided and supply lines limited to metallic circuits, as required in urban districts by rule 215 C. Such a flow of current would be considered objectionable, but since this is not a protective ground, this case was not contemplated as coming within the application of this rule.

(d) **Equipment and wire runways.**—Accessibility of the ground connection, where it is attached both to the equipment and the ground, is an important matter, because this enables the connections to be inspected after the equipment has been installed. On the other hand, if concealed, corrosion and deterioration could not be detected and remedied. Corroded connections sometimes render the ground ineffective, and thus its purpose is defeated. In some instances plumbers and others have had occasion to disconnect grounding wires and clamps for the purpose of repairing piping. They have frequently been left disconnected, but in some cases the fact that the point of connection was accessible disclosed this neglect, which was promptly remedied.

It is not intended that each length of conduit and each piece of equipment be separately grounded by independent grounding wires. Where a metal conduit or raceway system is employed it is sufficient to properly bond the different sections together either by separate bonds or through the junction boxes by scraping off paint and screwing the bushings and locknuts up tight. Galvanized conduit and fittings may provide proper electrical continuity between the separate sections, and tests have not shown enameled conduit deficient in this respect. However, locknuts and bushings, owing to careless workmanship, are not reliable for making electrical connection, and dependence should not be placed upon them where the voltage involved exceeds 150. Jumpers suitable for connecting around boxes are now commercially available.

(e) **Service conduit.**—The service conduit where grounding is required should not be grounded through the interior conduit but should have a grounding wire running directly from it. This is to prevent the possible passage of heavy currents originating outside the building through the interior conduit in case the conduit system were not grounded at the service conduit.

93. Grounding Conductor.

(a) **Material and continuity.**—Copper is the usual material for grounding conductors. Aluminum might be used in some rare instances, as where aluminum conductors are used on outdoor lines. Copper-covered steel is suitable. The corrodibility of iron and steel makes them generally unsuitable for grounding conductors, which are frequently installed in damp or moist locations where corrosion is likely to occur. Fuses, circuit-breakers, and switches are not permitted in the grounding conductor except under the conditions mentioned. The loss of the ground connection through operation of a fuse, circuit-breaker, or switch would often defeat the purpose of the ground.

(b) **Size and capacity.**—The minimum allowable size of grounding conductors is determined principally by mechanical considerations, for they are more or less liable to mechanical injury and must, therefore, be strong enough to resist any strain that they are likely to be subjected to. The general practice in electrical construction has been to place the minimum size at No. 6 copper, but this is mandatory only for lightning arresters, No. 8 being now permitted for circuits and service conduits, and No. 10 for dead parts protected by small fuses. Larger sizes are necessary in some cases, of course, to supply the necessary current-carrying capacity.

For equipment, especially equipment operating from grounded secondary circuits, the hazard in case of loss of ground connection is less, and the size of the grounding wire is determined more by the amount of current it may be required to carry than by mechanical considerations. This current in turn is determined by the rated capacity of the smallest fuse in the circuit supplying the equipment.

(c) **Mechanical protection and guarding against contact.**—The path of the grounding wire, especially from circuits carrying current, should be as far as possible out of the reach of persons, for it is to be considered dangerous, and as much care should be taken to prevent contact of persons with it as would ordinarily be taken with a low-voltage circuit wire. Where practicable this can best be done by bringing it to ground at a point directly over the place where the pipe or electrode is buried. The part near the ground and within reach can then be guarded against mechanical injury and contact by persons, preferably with guards of insulating material. It will be noted that the rules do not require guarding of the grounding wires in rural districts, but on account of children it is advisable at least to prevent ready contact with them in all places.

On account of the choking effects arising from metal guards which completely surround the wire, these should be used only where there is little probability of the passage of alternating or oscillating currents.

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On poles and for indoor work wood molding offers a very suitable protection for the grounding wire.

94. Ground Connections.

(a) **Piping systems.**—On account of the great extent of water-pipe systems and the good conductance of their joints they constitute the best means of grounding electric circuits and equipment. The resistance of water-pipe grounds is, in general, less than 0.25 ohm, the latter figure representing a maximum value. By far the larger number measure 0.1 ohm or less. The growing practice of using leadite instead of lead for the joints of cast-iron pipe, however, may render newly installed water-pipe systems less desirable for grounding purposes.

Some managers and owners of waterworks systems in days gone by have had unfortunate experiences from electrolysis due to the return current from electric railways, and they thought that any electric wire connected to their pipes might give trouble. This is not the case, and it should be borne in mind that the protective grounding wire of other circuits carries no working current, and the passage of current due to the breakdown of a transformer or other cross with a foreign circuit lasts only a short time—just long enough to blow a fuse or trip a circuit-breaker. It should also be remembered that most utilization circuits carry alternating current, and no harm from electrolysis would result even in case of current flow through the pipes.

Operators of water-supply systems have recognized the distinction between the action of different kinds of current from different sources and realize that the connection of secondary distribution systems to the water pipes is not injurious. The following paragraph is quoted from a resolution adopted by the American Water Works Association at its meeting in 1927.

The American Water Works Association approves the practice of grounding the secondaries of lighting transformers on water pipes for the purpose of safeguarding life and property, provided that appreciable electric current flows over such ground connections only during comparatively short and infrequent intervals when the ground connections are fulfilling their specific protective purposes, and provided that such ground connections impose no responsibility upon the pipe-owning company.

The use of water-pipe systems for grounding under the provisions of these rules may always be granted without

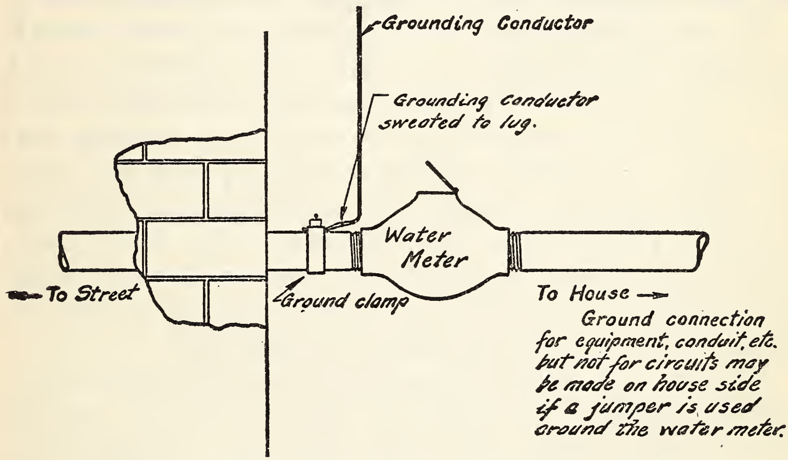

Fig. 3.—*Method of making grounding connection*

fear of damage from the circuits so grounded. There is also no possibility of injury to water-company employees if the simple precaution is observed of having the electric company remove grounding wires before work is done on pipes. The chances of injury are remote without removal of the grounding wire, but its disconnection entirely obviates the chance of injury from electrical causes. This method of grounding is illustrated in Figure 3.

On account of insulating joints and also the danger of fires or explosions, gas pipes should not be used for grounding where water-pipes are available. Where there are gas pipes there are usually also water pipes, so necessity for their use seldom arises.

(b) **Alternate methods.**—Where alternate means of grounding are used, such as well casings, drains, and other underground metallic structures of only local extent, care should be exercised, because many such grounds which appear to be good and sufficient for protective purposes turn out to be very poor at certain seasons of the year on account of drying of the soil, especially when the soil is sandy.

The metal frame of a building, where no buried metallic structures are available, may make a very effective ground, since the protection of persons does not require that circuits or equipment be connected to the earth itself, but only that no dangerous potential differences exist between the circuit or equipment in question and surrounding conducting objects. These objects include metal walls, damp floors, and heating piping, and where all these are bonded to the steel frame of a building the latter constitutes an efficient protective ground for the circuits or equipment.

Since grounds at building services are prohibited for direct-current systems by rule 92 (*a*), the grounding to building frames will be made only from equipment or alternating-current circuits. Where injury to the metallic reinforcement or frame of a building might result from its grounding as required by rule 94, through electrolytic action of earth currents, there will usually be closely neighboring water pipes which would be used for grounding rather than the building frame, while, on the other hand, earth currents from railway tracks are unlikely to be serious in regions so sparsely settled that no water system is installed.

If metal-clad buildings are exposed to accidental contact with circuits, the grounding of the metal covering is very advisable to protect passers-by from shock. This particularly is the case when the metal covering is insulated from ground by a masonry foundation or wood supports.

(c) **Artificial grounds.**—By "artificial ground" is meant an electrode of any form buried in the ground for the special purpose of attaching a grounding wire to it. The extent of such electrodes is usually limited, with a consequent high resistance as compared with water pipes. Their use should be resorted to only in the absence of more desirable means.

(d) **Grounds to railway returns.**—Protective grounds to railway returns are restricted to railway lightning arresters because of the potential differences arising from the railway return current, which might be shunted into buildings and cause electrolytic or other damage.

95. Method.

(a) **Piping.**—The use of ground connections from circuits to piping systems in buildings, except immediately at water-pipe service, should be discouraged, since any such interior piping system is likely to be disconnected for repairs, and if the circuit has only one ground connection such connection might then raise the potential of the system concerned above that of other piping systems in the same building, endangering the occupants. The use of such piping systems for the grounding of equipment frames is not attended by the same hazard, since the loss of such a ground connection will ordinarily not cause a rise of potential in the disconnected piping because the equipment frame is insulated from the circuit within. The hazard in this case lies only in the contingency that a leakage simultaneously exists between the frame and the circuits inside the equipment, a condition which would probably lead to early discovery and correction.

Gas piping is not commonly used for grounding anything except lighting fixtures, because of the danger of igniting the gas, in case the pipe is broken and a spark results. In the past there have been some severe accidents due to ignition of gas by a spark formed when workmen disconnected runs of gas piping carrying current. This current in all of the cases reported was stray railway current, but it can easily be appreciated that current from lighting circuits grounded to gas pipes might possibly produce similar results.

In the only case where grounding to gas pipes is permissible—namely, in the case of small fixtures—the gas pipe must be well bonded to the water-pipe system of the building. The best place to connect to water piping is on the street side of water meters, but not infrequently cases arise where the meter is not within the building, so that connection must be made on the building side. It is then necessary to shunt the water meter to avoid breaking the ground connection in the event of removal of the meter.

(b) **Ground clamps.**—There has been during recent years a notable development in the equipment available for making ground connections, and there are now on the market a number of suitable devices for this purpose. Many ground clamps used in the past were of rather flimsy construction, making their usefulness uncertain. When made of copper, clamps should be not less than one-sixteenth inch in thickness, should be provided with strong bolts and lugs for attaching them to the pipe, and should have some means for adjusting them to fit the particular pipe to which they are attached. If made of iron, clamps should be galvanized and so made that the protective coating is not broken by bending in putting them on. It is urged that preference be given to clamps of substantial construction.

(c) **Contact surfaces.**—In every case where electrical continuity is desired for the purpose of grounding or bonding, the surfaces of the metals where they come in contact with each other should be carefuly cleaned of enamel, paint, rust, or other nonconducting material. This assures low resistance of the ground connection.

(d) **Artificial grounds.**—Artificial grounds may be made by means of driven pipes, buried plates, or buried strips of metal. The first two are most generally used. With regard to driven pipes it has been found that sizes ranging from 1 to 1¼ inches internal diameter are the most economical; that is, larger sizes do not give returns in proportion to the expense involved. The customary length is about 8 feet in conducting soil. A layer of dry soil on the surface of course necessitates greater length of pipe, but after 8 feet of conducting soil has been penetrated, increased length does not give proportionate decrease of resistance. It is more economical to use several grounds in parallel, because if they are spaced 6 feet or more apart the total resistance varies approximately inversely as the number.

It requires nearly 6 feet of 1-inch pipe to provide 2 square feet of superficial area, or 12 feet for 4 square feet. For 1¼-inch pipe the respective lengths are 4.5 and 9 feet; for 1½-inch pipe, 4 and 8 feet.

To insure good connection with driven pipes, one power company, after plugging the pipe, pours around the conductor which is to be attached to it a mixture of molten lead and antimony in the proportion of 75 parts of lead to 25 parts of antimony. This alloy is similar to type metal and expands upon freezing, thus giving a tight joint, which is rigid and of low resistance.

The size of plates need hardly be greater than 10 square feet. Larger sizes may provide for a greater rate of dissipation of energy in case of current flow, but added area after the first 10 square feet does not result in anything like a proportionate decrease of resistance. If it is necessary to attain a resistance much less than that provided by a plate of medium size, say 6 to 10 square feet, several plates in parallel had better be used, placing them well apart.

The resistance of grounds made with buried strips varies almost inversely as the length of the strip. This type of ground is best suited to rocky locations where the top soil is shallow, because they can be laid in trenches to almost any length and give the least resistance for the amount of metal used of any of the different types.

The materials most used in making artificial grounds are galvanized iron for pipes, copper-covered steel for rods, and copper for the plates or strips. Galvanized-iron or cast-iron plates may be used, but it is not to be considered advisable on account of the possibility of corrosion of the galvanized iron, which, in the case of a plate, is difficult to detect without digging it up, and on account of weight and cost in the case of cast iron. Corrosion of driven pipes can, on the other hand, readily be detected near the surface with very little labor.

To reduce the resistance of artificial grounds by 25 to 50 per cent, salt may be used in the amounts of 75 or 100 pounds for a medium-sized plate and about the same amount for a driven pipe. The salt should be buried with the plate, or in the ground near the top of the pipe, and allowed to dissolve in the soil moisture and percolate through the ground. Percolation can be hastened by soaking the ground with water, but this is not necessary.

Coke may be used to reduce the resistance of plate grounds, but to effect a material decrease requires a large amount of coke and considerable digging, which can be avoided by the use of salt, so the use of coke is hardly to be recommended generally.

The corrosive effects of coke are very destructive to galvanized iron, but not so much so to cast iron. Galvanized iron is largely destroyed in a few years. Coke seems to have no effect on copper, or at least not a marked effect. Copper buried in coke for 5½ years showed no appreciable deterioration. Salt seems to have no serious corrosive effects, specimens of galvanized iron buried 6 years in salted ground still being in good condition.

96. Ground Resistance.

(a) **Limits.**—The necessity for low resistance in ground connections is readily apparent. A ground of 10 ohms resistance, carrying 100 amperes, less than the capacity of many primary distribution circuits, would cause 1,000 volts drop between the grounded conductor of the secondary and earth. Clearly, under these conditions, such a ground connection would not eliminate the life hazard. The power expended by the current passing through the ground connection would be 100 kilowatts, and the resulting heat might become a source of fire hazard or might rapidly dry out the earth in close proximity to the electrode and increase the resistance, thus raising the voltage still higher.

Where, however, a secondary circuit is exposed only through transformer windings and not by reason of running under high-voltage circuits, the only fuse which need blow to protect against high potentials on the secondary is the primary fuse of the transformer. In this case a single ground of 25 ohms resistance would give rise to 250 volts between secondary and ground without enough current flowing to blow a 10-ampere fuse. This may not be considered dangerous, but even here the use of two grounds and two grounding conductors would be very desirable to provide insurance against loss of protection through corrosion or breakage of the grounding wire. In case there is more than one service from the transformer, the multiple grounds are easily obtained.

There are cases where it is desirable to limit the value of current flowing over the grounding wire. This may occur, for example, in low-voltage direct-current systems grounded at the generating station or substation, where a short circuit is likely to be very severe.

To prevent an excessive current flowing in case of a short circuit through the ground, a small definite resistance may be inserted in the ground connection. This practice is common in Great Britain. It is evident that 1 ohm in a 120 or 240 volt circuit will limit the short-circuit current without preventing the operation of circuit-breakers set for moderate currents.

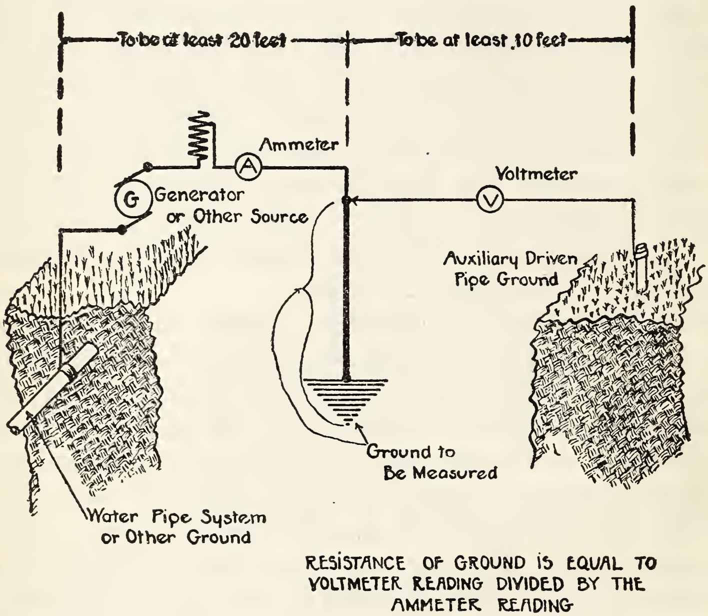

FIG. 4.—*Method of checking ground resistance*

(b) **Checking.**—The ammeter-voltmeter method of checking the resistance of ground connections, illustrated in Figure 4, is the most reliable and satisfactory, but if current is not available the Kohlrausch bridge method may be used with a fair degree of success. This employs alternating current derived from a dry battery with a buzzer and transformer, and unless conditions are very unfavorable, especially with regard to dryness of the soil or the presence of too much alternating or pulsating leakage current, results may be obtained with an accuracy better than 10 per cent in nearly all cases, and in most cases within 2 or 3 per cent. A detailed description of the different methods of measuring the resistance of ground connections is given in B. S. Technologic Paper No. 108, Ground Connections for Electrical Systems, page 145.

Instruments especially designed for measuring resistance of ground connections are now commercially available, and provide all necessary accuracy by the use of easily portable apparatus.

97. Separate Grounding Conductors and Grounds.

(a) Grounding conductors.—One objection to the common use of grounding wires for different classes of equipment is the danger that damage to a single wire will leave a large amount of equipment unprotected. Hence, the most desirable degree of safety requires separate grounding wires from the classes of equipment enumerated in this rule. There is also the possibility that the impedance of the grounding wire may be sufficient to give rise to dangerous potential differences between equipment and ground in the event of heavy current flow over the common grounding wire from one of the circuits or sources of current to which it is connected.

The failure of a common grounding wire through mechanical injury or otherwise may even create a hazard which would not exist if separate grounds were used. Frames of equipment are ordinarily dead, but if connected to the grounded conductor of a circuit, and the ground connection is then lost, a potential above ground may be imposed on the frame, creating a grave hazard of shock to persons. This danger of being made alive by connection to an ungrounded conductor is sufficient to warrant the prohibition of a common grounding conductor for circuits and non-current-carrying parts. Connection to the same ground does not create this hazard, since the two can not be in electrical connection with each other without being also connected to the ground. In the case of multiple grounds to water-pipe systems, the contingency of losing the ground connection is rather remote, and an exception is consequently made in this case for a common grounding wire for equipment and secondary circuits.

(b) **Arrester grounds.**—Separate artificial grounds for lightning arresters are required because in the event of a discharge over the arrester the rate of current flow is so great that a dangerous potential difference would be set up between the grounding wire and ground on account of the resistance of the ground connection. This potential difference would be impressed upon any other circuit or equipment that might have a common ground with the arrester. To eliminate this possibility, which is a serious one, separate artificial grounds should be used for arresters.

Part. 1.—RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRICAL SUPPLY STATIONS AND EQUIPMENT

Sec. 10. PROTECTIVE ARRANGEMENTS OF STATIONS AND SUBSTATIONS

100. Scope of the Rules.

It is important to observe the distinction between the requirements of the code for station equipment and for utilization equipment, even when the former is of the same nature as the latter. A somewhat less general use of guards and less complete isolation is allowable with station equipment which is accessible only to qualified attendants than is allowable with electrical utilization equipment which is accessible to unqualified persons, as is the case usually in workshops, mercantile establishments, and other similar places. (See also discussion of rule 300.)

101. Application of the Rules and Exemptions.

(a) **Application and waiving of rules.**—The rules are intended to be observed completely in new work under ordinary conditions. The rules are intended to be observed also in extensions or reconstructions, "where practicable," this applying, of course, only to the part of the entire installation which is actually an extension or is actually reconstructed.

The rules have been written so as not to limit, more than is necessary to insure safety, the number of types of construction that may be used to comply with them. It is, however, recognized that exceptional cases will arise where good judgment will dictate a modification of the literal requirements of the rules. It is also recognized that working methods may sometimes be as effective in securing safety in the operation of an electrical supply station as some types of equipment safeguarded by construction.

Experimental installations and methods of construction and operation should, in general, be allowed by administrative authorities under favorable conditions if the experiments entail no material hazards and are likely to lead to improvements in the art. The administrative authorities under such circumstances should supervise and subsequently inspect the installations, so that the advantages or disadvantages of the experimental installations may be determined in comparison with the methods specified in the rules.

(b) **Intent of rules.**—The replacement of existing construction to secure compliance of the entire installation with the rules would in most cases involve unwarranted expense and is, in general, not contemplated. When, however, an extension or reconstruction is being carried out for other reasons and is of relatively large proportions, it may be advisable to reconstruct certain other portions of the installation, in order to suitably safeguard it in conformity with the rules. In some cases it will be feasible and proper to reconstruct, as necessary, the entire installation to comply with the rules.

In considering existing installations it is evident that some rules can be made effective at once without unwarranted expense and so assist in safeguarding the attendants, and frequently with distinct benefit to service no less than to safety. Such improvements should be made as rapidly as possible after the rules become effective, and a program should be arranged for future replacements and improvements on some reasonable schedule having the approval of the administrative authority. Such reconstruction can, of course, usually be done most economically at a time when important extensions or reconstructions are being undertaken for other reasons than accident prevention, as noted above.

On the other hand, it may be quite impracticable when extensions or reconstructions are undertaken for other reasons than accident prevention to comply fully with the rules. The replacement of one switchboard panel having live parts of more than 750 volts within 6 feet from floor line by another panel having 6-foot clearance for such live parts might be impracticable, since the necessary busses might be complicated and actually dangerous. Other instances where compliance will be impracticable will be clear to the administrative authority and need not be insisted on, provided the existing installation is reasonably safe.

Guarding and grounding are often feasible with existing equipment at no greater expense than would be required for similar guarding or grounding of new equipment. In such cases this protection should be provided. In other cases, due to very restricted space, the provision of such protection might be impracticable. Such questions should be left to the proper administrative authority for settlement.

102. General Requirements.

(a) **Inclosure of rooms and spaces.**—To assure against service interruptions and against injury to both equipment and unqualified persons, the approach of trespassers should be prevented by use of suitable inclosing walls or fences. At entrances signs warning against entrance should be displayed. Attendants on duty should be instructed to warn unauthorized persons against access to spaces occupied by electrical supply equipment. By these means the attendant is also safeguarded against dangers arising from distraction of his attention. Locking entrances is recommended when no attendant is on duty within.

(b) **Rooms and spaces.**—Power houses, transformer and switch stations, and rooms should not be constructed of combustible material, since a fire in such a structure may be particularly disastrous. In addition to noncombustible walls, floors, and roofs, there should be as little combustible material as possible inside the building. Use of wooden floors and roofs will violate the fundamental intent of the rule. Storage of material not only presents a fire hazard which would be greatly increased by the presence of electrical equipment but creates a life hazard to the operator. Exits might be blocked or working space cramped to such an extent that in case of trouble developing the operator would be impeded.

No extended manufacturing process can be carried on in the immediate vicinity of electrical generating equipment without endangering persons engaged in manufacturing as well as those attending electrical equipment. The attention of electrical operators is distracted by the presence of other processes, and this in itself presents a serious danger, while the continuity of service and life of electrical equipment will sometimes suffer, and the fire hazard is increased by electrical equipment in combustible surroundings.

The liability of arcing at contacts or connections, especially at switches, fuses, and brushes, makes the existence of inflammable gas and finely divided combustible material highly dangerous even where the operator can endure such atmospheric conditions. Grain elevators, flour and cotton mills, coal-storage plants, and nearly all industries where lint, dust, or inflammable gas is customary should have substations or generating rooms carefully segregated from the dust-producing parts of the plant. Acid fumes should also be avoided, inasmuch as the deteriorating effect upon insulation and machinery creates an additional hazard to life.

Adequate ventilation decreases the accumulation of moisture and dampness on surfaces and prevents the concentration in dangerous quantities of inflammable flyings and gases. Sanitary conditions are also improved. The primary value of ventilation is, however, a check on the accumulation of heat about electrical apparatus in order that excessive temperatures imperiling the apparatus when loaded to its rated capacity may be avoided.

It is recommended that the presence of an abnormal or dangerous accumulation of explosive gases, acid fumes, etc., be promptly and automatically indicated by a distinct audible signal. (See discussion below on audible signals.)

Generating stations exposed to weather, in wet tunnels, or for any reason normally damp should be designed and equipped as outdoor stations and for the prevailing atmospheric conditions. Live parts should be placed in weatherproof cases unless guarded against contact or isolated by elevation.

Moisture about equipment not specially designed for such conditions leads to frequent breakdowns, and these endanger both attendants and service. Attendants near live parts in damp locations are exposed to leakage over damp surfaces and through deteriorated or moisture-laden insulation. In case of shock where dampness prevails the better contacts tend to increase the seriousness of the injury.

(c) **Rotating machinery.**—Rotating machinery should always be considered as "live load" in determining the strength of supporting structures or foundations, thus favoring adequate support, reduction of vibration, and the consequent wear on the bearings and insulation. Since creeping is usually possible, the machinery should be bolted down.

A desirable adjunct to any extensive plant is an electric code calling system. This will prove a very definite element of safety in case of fire, failure of power, running away of a machine, accident to an employee, sudden and unexpected demand for power, malicious act, etc. A code calling system will also increase materially the efficiency and economy of operation under the normal conditions. Such a system consists of a control commutator and of horns, bells, whistles, electric lamps, etc., distributed throughout the plant in such locations that at least one of them may be heard or seen from any place. The central commutator enables a different number of blasts to be sounded in various combinations, each combination signifying either a call for a definite employee, an announcement of an abnormal condition, or an order to perform a certain act.

The most important audible signals should be connected to an emergency source of power, or means should be provided for promptly and automatically switching them over to such a source should the regular source of supply fail.

Loud-speaking telephones and microphones can be installed in dangerous locations, such as high-tension compartments, so that a person working there can notify of his distress by shouting from where he may be caught. Such telephones are also recommended for communications between the load dispatcher, the operating superintendent, and the switchboard operators.

103. Illumination.

(a) **Under normal conditions.**—Good modern practice provides adequate artificial illumination for all rooms and spaces containing electrical equipment. Uniform intensities over working spaces, special illumination at points where reading or visual precision is required, are indications of good practice. There should be no deep shadows in working spaces or passageways. Stairs, in particular, should be well illuminated, and this may be accomplished by placing the source over or in front of the first riser, so that both riser and tread will receive proper illumination.

The intensities in Table 1 represent a mandatory minimum in addition to values taken from good modern practice. Reference is made to the Code of Lighting Factories, Mills, and Other Work Places, A. E. S. C. A 11–1921, for more detailed information regarding good lighting practice. Illumination measurements are to be made on the vertical, horizontal, or intermediate plane, as the case may be.

In locations where continuous illumination is not necessary, but in which an attendant may necessarily enter in case of emergency, a means of illumination should be constantly ready for use.

It would be well to provide moderate illumination over yards, paths, roads, etc., outside of the station, thus insuring safe access both to and from the station.

(b) **Emergency source.**—Operators should not be exposed to the danger of operating switches or performing other operations about live parts in rooms which would be suddenly darkened by the failure of current.

In some cases emergency lamps are automatically lighted by the failure of the usual energy supply.

Many stations are equipped with a storage battery for the purpose of supplying emergency illumination. In some instances this battery is especially provided for the purpose, while in others it is used principally to supply energy for operating relay systems and similar equipment. The installation of an automatic relay or other device which will throw this source on the lighting system when the regular illumination fails has found much favor. In certain cases oil lanterns may provide a sufficient emergency source of illumination, although not suitable for battery rooms.

The use of gas jets obtaining their gas supply from a reliable source is also often recommended. Open-flame lighting should not be used where inflammable gases or flyings exist and is prohibited in storage-battery rooms by rule 134.

Simultaneous station illumination from two separate sources, one being emergency lighting source, is coming into favor. It eliminates the time required for transferring in case the main source fails and the other source is not connected automatically.

(c) **Fixtures and pendants.**—The use of portable cords in the operation and repair of station equipment should be discouraged by provision of thoroughly adequate permanent means for illumination. When peculiar arrangment of equipment may necessitate even occasional use of portable lamps and other portable equipment during station operation, provision should be made for permanently fixed receptacles, conveniently located with respect to the equipment worked on and safely accessible to the user. Provision of suitable short cords at convenient points will eliminate (under careful management) the use of long cords attached to distant receptacles and hauled over floors and about equipment.

The use of long cords attached directly to bus bars, switch terminals or blades, and similar makeshifts is frequently the cause of sever burns, eye injuries, and not a few fatalities. The importance of carefully planning the installation to reduce such accidents is becoming generally recognized in modern practice.

(d) **Attachment plugs.**—The rule requiring that all poles of cable connectors shall be disconnected by a single operation may be met by the swivel-type connector, but this is not as desirable as the bayonet type, which disconnects all poles simultaneously and can, therefore, not be so interrupted during the operation of disconnection as to leave a single pole connected and the portable cord and device possibly alive from this source.

The fact that tension in the portable conductors tends to disconnect the bayonet-type connector is a desirable feature from a safety point of view.

104. Floors, Floor Openings, Passageways, Stairs.

(a) **Floors.**—Falls, hitting obstructions, and similar mechanical accidents are responsible for the greater proportion of all personal injuries in stations. It is highly important that spaces about electrical equipment be kept neat and clean and free from extraneous matter.

Unevenness in floors is responsible for many accidents. Iron or tile floors may be dangerously smooth or slippery. Doorway treads, stair treads, and frequently used passageways may develop dangerously slippery surfaces which can be avoided by employing antislip treads or antislip materials manufactured for this purpose. Such materials are generally available and can be readily applied subsequent to the construction of the plant.

(b) **Passageways.**—Infrequently occupied passageways or spaces, such as bus bar or pipe chambers, where the conductors are guarded by insulating coverings, metal sheaths or barriers, may with reasonable safety have less than 6.5 feet clear head room, since inadvertent movements are less liable to be made in such places.

Passageways or spaces frequently used by attendants in the operation of the station should be of ample dimensions to permit their rapid and safe traverse.

(c) **Railings.**—Floors should have no abrupt changes of level. Unevenness in floors is responsible for many accidents. The use of railings where considerable differences in floor level exists is a desirable practice, and many companies use them where the difference in level is much less than that for which a railing is required by the rule.

Insurance underwriters have established 18 inches as the maximum depth of floor opening which may be unprotected. This is a recognized standard.

(d) **Stair guards.**—Stairs are a source of frequent accident. The seriousness of the hazard is greatly reduced by handrails. Long and steep stairs, especially if not very well illuminated, may well be supplied with guards at the heads, such as gates or sliding pipe sections.

Insurance underwriters have defined a flight of stairs as consisting of "not less than four risers or a series of risers and landing not exceeding one story in height."

(e) **Continuity.**—The varied and extensive use of ladders makes them a subject of considerable hazard. Many station designers reduce the hazards involved by using care and foresight in their location. Except on very steep ladders handrails are desirable.

Portable ladders for use in stations should always be insulating. Wooden ladders should not be reinforced with metal strips or wire, as accidental contact with high-voltage conductors may then result in bringing the dangerous potential to the person using the ladder.

(f) **Floor toe boards.**—Floor toe boards aid materially in preventing the likelihood of tools or other material falling or being pushed over the edge. Many serious accidents to operators may be attributed to falling tools, etc., and in eliminating these personal hazards it is evident that additional protection is secured for rotating machinery.

(g) **Stair toe boards.**—Toe boards where used on stairways may be attached to the underside of the tread next above, and so permit a small space above each tread for cleaning away grease and dirt.

105. Exits.

(a) **Clear exits.**—Exits from rooms and working spaces about electrical equipment should be kept clear, since in case of accident they provide not only means for escape but also ready access for emergency measures.

(b) **Double exits.**—More than one exit is particularly desirable from the back of switchboards, from narrow galleries, and long passageways, since in case of dangerous arcing, smoke, steam, or other dangerous condition, a single exit may be shut off. A slight injury to an attendant, such as burns or flashed eyes, or even slight faintness, may make the traversing of a long passageway to a single exit highly dangerous, since under such circumstances one is more liable to stumble against live or moving parts adjacent to the passage. Pipe and wire tunnels are particularly a source of personal hazard, because we find here a conflict between measures for fire prevention and more direct personal safety. Openings at such points assist in spreading fire, but automatic fire doors obviate this. When distributing mains are run underground a conduit system is safest; a tunnel for wires and pipes may be preferred, however. The tunnel should not open directly into the power station or transformer house, nor into any important room or building; separating walls should be used. For safety to persons who might be in the tunnel during accident, means for rapid exit should be provided at both ends. Small fire doors through the separating walls, or manholes readily opened from the inside may be used.

106. Fire-Fighting Appliances.

(a) **Fire extinguishers.**—The use of soda-acid extinguishers on live parts, except those at very low voltages, endangers the operator. This is also true when a hose stream is played upon live parts but a short distance away and at somewhat higher voltages. Both may also seriously injure the electrical equipment. Use of special extinguishing liquids which are nonconducting, on the other hand, entails no danger of shock if the person does not bring the metal container into actual contact with live parts.

Soda-acid extinguishers, therefore, should not generally be installed close to electrical equipment, since safer types of extinguishers are available for such locations. Care should be exercised in the selection of extinguishers employing special nonconducting liquids; those operated by liquid pumps have proved more reliable in practice than those depending in any way on air or gas pressure.

An extinguishing liquid having a carbon-tetrachloride base will generate fumes which are intensely irritating and are also poisonous; and it is unsafe for use in confined spaces. On account of the rapid generation of such fumes a fire can not be fought indoors for any considerable length of time. It is recommended that great caution be exercised in the use of carbon-tetrachloride extinguishers on fires in closely confined places where the conditions are such that the user can not escape without breathing the fumes. A gas mask may be used for protection against the fumes.

Of more recent development are hand extinguishers which use carbonic gas (or snow), which is more free from objection and is harmless to electrical apparatus.

Sand or similar material will smother an electric arc, and pails of sand have been used for switchboard fires. Sawdust is effective in smothering oil fires in small containers but should preferably have bicarbonate of soda mixed with it in the proportion of 10 pounds to a bushel of sawdust. An advantage of these materials is that they do not evaporate and are not likely to become ineffective in long stand-by service. The weight of sand makes it difficult to use effectively, and it has a deteriorating effect upon bearings. Sawdust constitutes a fire hazard in itself unless mounted where its burning can do no damage.

The above discussion applies more particularly to hand extinguishers or small emergency fire apparatus. For the protection of electrical apparatus containing large quantities of oil it will be advisable to arrange it so that approved fire-extinguishing material may be introduced in the tanks or inclosures. For use especially on oil fires the extinguishing material is frequently a carbon-dioxide foam. For protection of large alternators the extinguishing material may be steam or carbon dioxide gas introduced into the ducts of the cooling system.

Approved audible signals for sounding fire alarms should be installed and connected to a code-calling device. It should be possible to hear at least one gong or horn at any given point. The code adopted for sounding fire alarms should clearly indicate the location of the fire.

Alarm bells may be controlled by fusible links, thermostatic devices, etc., similar to sprinkler heads, and may be preferable to a sprinkler system where an attendant is always within call, on account of the damage possible from water.

(b) Temperature conditions.—Fire extinguishers should not be installed near steam pipes, radiators, or other heating devices, or in locations subject to high temperatures. In cold climates provision should be made to protect extinguishers from exposure to low temperature which would render them temporarily ineffective. The commercial type of carbon-tetrachloride extinguisher is not affected adversely within the range of temperature between 60° C. (140° F.) and −40° C. (−40° F.).

Commercial carbon tetrachloride freezes at a temperature of about −10° C. The liquid used in commercial fire extinguishers, although having a carbon-tetrachloride base, includes also admixtures of materials to depress the freezing point. For this and other reasons it is important to follow directions supplied with the extinguisher when refilling it.

Soda-acid and foam types of extinguishers are rendered useless by severe freezing temperatures. Near apparatus exposed to low temperatures, fiber pails of calcium-chloride brine are occasionally installed for emergency use. None of these are recommended for fires in electrical equipment.

107. Oil-Filled Apparatus.

Failures of oil-filled apparatus that have resulted in personal injuries or damage to property have, in general, been attributable to oil switches, transformers, regulators, and lightning arresters. Among the principal controlling factors as regards severity of the hazard is the quantity of oil involved, the capacity of the system to which the apparatus is connected, and proximity to the source of power.

The causes which have led up to the failures include lightning, short-circuit stresses in equipment, mechanical failure of structural parts, the use of switches and equipment unsuited to the system capacities to which they were connected, and careless or unskilled operation. In reviewing the nature and causes of the various occurrences, it seemed to the committee when studying this matter, that no single rule or set of rules could be devised that would adequately meet every condition under which this class of equipment is regularly operated.

A large factor in the oil-filled-apparatus hazard is the rapid increase in system capacities and changes in distribution methods. For example, oil-filled apparatus of standard types may be installed or in use on a system with a generating capacity of 10,000 or 50,000 kilovolt-amperes under which condition the serious failure of equipment may be remote. Subsequently the capacity of the system may be multiplied many times, or through interconnections the original equipment may become part of a larger system and be entirely inadequate to meet the newer conditions with satisfactory reliability. If the remedy requires the substitution of more modern or substantial equipment, it will be obvious that cost considerations may prevent such a course being immediately followed.

To design for an ultimate maximum duty in new installations is impracticable when future conditions can not be determined.

It is intended, therefore, that this code rule be considered of a general nature, subject to liberal interpretation under all conditions.

Precautions should be taken to localize trouble that may occur. Failure of cases containing oil should not be permitted to result in spreading burning oil where it places operators in danger. On balconies or upper floors means should be provided to effectively prevent flowing oil from reaching floors below. A drainage system for oil not only affords added protection, but frequently provides a convenient means for handling the oil during routine operation and maintenance.

(a) **Oil switches or circuit-breakers.**—Manually operated oil switches, motor starters, and induction regulators in individual locations, or small groups of such apparatus, may involve such small hazard as not to justify the expense of isolating inclosures or oil-drainage systems. Oil switches and circuit-breakers of certain types may be safely installed on the rear of switchboard panels when they are connected to a system of limited capacity, whereas if connected to a system of large capacity they should be installed in fireproof switch cells, as they may prove at times to be entirely inadequate to function properly under the more severe conditions which are occasionally imposed.

Because of the possibility of violent failure of oil switches they should be located so as to minimize the possibility of damage or injury from scattered burning oil.

Drainage gutters provided for oil switches, instrument transformers, etc., containing oil in quantities small enough to permit close approach by attendants during burning, may lead directly to the sewer pipes in fire-resistive buildings, if local regulations permit. When the apparatus contains oil in sufficient quantities to cause hazard from explosion and fire by flooding the drainage system with burning and boiling oil, the drainage gutters should lead directly to a catch basin or point outside of the building where burning oil can do no damage.

(b) **Transformers, induction regulators, etc.**—Although modern oil-filled apparatus is greatly improved in design and construction as regards safety, it is believed that too much care can not be taken in the proper segregation of apparatus containing large quantities of oil.

Transformers and induction regulators if in large groups or if containing large total amounts of oil should, where practicable, be installed in fire-resistive inclosures, well ventilated to outside of the building to prevent dangerous accumulations of oil vapors. The inclosures should be free from apparatus likely to take fire from burning oil, subdivided to a reasonable extent, and should have doors or windows so located or arranged that burning oil would not be likely to pass through the inflammable material or apparatus outside of the inclosure.

(c) **Lightning arresters.**—It is advisable, where practicable, to install lightning arresters out of doors.

Sec. 11. PROTECTIVE ARRANGEMENTS OF EQUIPMENT

110. General Requirements.

In general, it is recommended that such rules of the National Electrical (Fire) Code as apply be complied with in the arrangement and protection of equipment and circuits. In general, those rules, by reducing fire hazard, also indirectly reduce life hazard.

111. Inspection.

(a) **Regular equipment.**—The value of systematically inspecting and testing equipment and circuits after operation has been established can not be too strongly urged. Gradual deterioration of the system will be detected, and injuries resulting from defective conditions will be avoided by proper repairs and replacements. Where a log book is kept, important defects should be entered to insure attention to them. The recording of defects also tends to improve design in new installations or extensions. Cleanliness, of course, retards deterioration.

(b) **Idle equipment.**—Equipment seldom used is likely to be neglected and so may be dangerous when placed in service. This can be avoided by periodic inspection or inspection before being put into service.

Where equipment is idle but not permanently removed from service, many companies have prime movers and other rotating apparatus periodically turned over and connections and wiring tested to assure safe and proper operation if suddenly called into service.

(c) **Emergency equipment.**—Emergency equipment can not be depended upon, especially after long periods of idleness, unless subjected to routine periodic inspection and test. Holding such equipment always in readiness is a large factor in the continuity of service. Requiring a written report or log aids materially in having periodical inspection of such equipment carried out.

(d) **New equipment.**—A thorough initial inspection of each installation of electrical equipment will be found desirable before placing it in service, however carefully the installation has been made, and inspection by some person other than one engaged in the work is always desirable with important installations, in addition to an inspection made by the installing engineer himself, however competent and sincere.

112. Guarding Shaft Ends, Pulleys and Belts, and Suddenly Moving Parts.

(a) **Transmission machinery.**—While guarding is, in general, necessary for moving parts near which persons are at work, it is ordinarily unnecessary to provide guards for very small or very slowly moving parts. However, projecting set screws, for instance, may be dangerous even on such slow or small parts. The Safety Code for Mechanical Power Transmission Apparatus, A. E. S. C. B 15–1927, covers the safeguarding of moving parts of equipment used in the mechanical transmission of power, including prime movers, intermediate equipment, and driven machines. This includes connecting rods, cranks, flywheels, shafting, spindles, pulleys, belts, link belts, chains, ropes and rope drives, gears, sprockets, friction drives, cams, couplings, clutches, counterweights, and other revolving or reciprocating parts. It seems undesirable to repeat such detailed requirements in these electrical rules.

(b) **Suddenly moving parts.**—Circuit-breaker levers and handles, governor levers, controller handles, and small parts which move suddenly have caused accidents which warrant consideration. Mechanical guards may be used, but preference is given the guarding of such parts by isolation when it is not necessary to make them accessible.

113. Protective Grounding.

(a) **Grounding method.**—The grounding of equipment for protection of persons must be thoroughly reliable or else it gives a false sense of security. To obtain reliable grounding requires very careful consideration of the attendant conditions. Since the method is in general the same for grounding whether in stations, on lines, or for utilization equipment and circuits, and the requirements are necessarily considerably detailed in order to provide a useful guide, it has been deemed best to place these detailed rules in section 9.

(b) **Grounding noncurrent-carrying metal parts.**—Where conditions of dampness exist, or acid, or acid fumes, the danger to persons from possible leakage to ungrounded machine frames is greatly increased because of good contacts possible, and even the lower voltages become dangerous. Where an explosive atmosphere exists, sparks must be avoided; careful grounding aids in accomplishing this result by making the frame of the same potential as surrounding objects.

While grounding of noncurrent-carrying metal parts is generally necessary, of course this is understood not to apply to such parts as card holders on switchboards, and similar parts very unlikely to become alive by leakage from live parts.

Such equipment as direct-current railway generators, rotaries, and switchboards, or direct-current arc machines and control boards, may sometimes present actually less hazard if guarded as permitted under this rule than if grounded. This is especially true if ungrounded live parts are exposed as at some so-called single-voltage switchboards.

When frames of such equipment are not permanently grounded, they should be effectively insulated from ground by a dielectric suitable for the maximum operating voltage and bonded to neighboring noncurrent-carrying metal parts. Grounded conduit should be kept well away from such insulated frames, so that short-circuits will not occur nor persons inadvertently make circuit between them. Partial and variable insulation (such as masonry or concrete usually affords) between the frame and adjacent grounded parts does not afford suitable protection either for attendant or equipment.

Small transformers, such as instrument transformers, may be protected to a degree from the hazard of breakdown to ground if the case is left ungrounded and so mounted that normally it is insulated from ground. This is permissible only if the hazard to persons is eliminated by isolating the transformer by elevation or by guarding it from persons by barriers or cells or by providing mats.

(c) **Grounding equipment during repairs.**—Electrical equipment on or about which work is occasionally done while separated from a source of electrical energy may be a source of personal hazard.

The operating rules of Part 4 provide for the elimination of such hazards. (See discussion of rules 423 and 424.)

114. Guarding Live Parts.

(a) **Where required.**—The intent of the rules is to secure safe installations from the life-hazard standpoint. Electrical apparatus is regularly manufactured according to commercial designs and not for a particular installation. Hence, it does not inherently provide the clearances called for by the table in rule 114 (*a*). The rules, therefore, provide for the necessary clearances for guarding and isolating electrical apparatus in its final installation. The tables are not intended to apply to clearances in or on electrical apparatus itself as a part of its design and manufacture. It is assumed that the manufacturer will provide the necessary clearances in or on his apparatus as may be required by the rules of the American Institute of Electrical Engineers. (See note to Table 2, rule 114.)

If live parts could be always perfectly guarded when persons are near them, accidents from electrical shock and burn would cease. Guarding for live parts must, however, be somewhat less than perfect with much station equipment during necessary inspection, repair, or adjustment. Quick access, where necessary, should not be obstructed by guards, as this may be essential to avoid unnecessary slowing down of operation or partial shutdown of service in emergencies. Otherwise public service and safety might be sacrificed to increase the operator's safety.

Carefully planned, permanent guards may, however, aid rather than delay service by making possible, with safety, repairs near live parts without the necessity of installing temporary protective devices or the shutting down of adjacent circuits. Guards also tend to prevent accidental short-circuits and the spread of short-circuits beyond the place of origin.

Guards, which protect under all conditions, are particularly necessary where, from the nature of the situation, dry insulating floors are impracticable or where the flooring affords an insecure footing.

It is not practicable to guard perfectly commutators, brush rings, and other parts of rotating machinery by construction. Adequate safety, however, may be secured for attendants by supplementing incomplete guarding with safe methods of operation. Brush rings may be effectively insulated by wrapping with cord or twine and coating with varnish.

The radius of guard zone, given in column 4, Table 2, may also be used as a minimum separation for attendants to keep between any material or object and live parts. During no condition of operation or maintenance should an attendant permit any material or tool not designed for the voltage, including a part of his body unprotected by insulating devices, within the distance specified as the guard-zone radius. See rule 422, B and C, for definite specifications of working clearances between persons and live parts.

Difficulty is often experienced by utilities when making repairs, replacements, or extensions to existing construction, in maintaining equipment, either existing or new, in safe condition. It is sometimes necessary to remove the permanent barriers or other safeguards to do this work which may involve hazards to unauthorized persons, such as ironworkers or brick masons doing the construction, unless adequate temporary guards are provided. Care should accordingly be exercised.

When new equipment is being installed and is ready for testing, precautions should be taken to guard against accidental contact by persons in the vicinity or against defects or improper connections or arrangements of apparatus. This can be done either by the installation of temporary guards or barriers or warning signs, depending on the degree of hazard. Lengths of red or white tape around dangerous

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areas are employed on the testing floors of some manufacturing companies.

Equipment which is not designed for outside use is liable to become damaged by weather conditions and thus produce a hazard when it is put in service under normal operating conditions. Accumulations of dust, flyings, acid, or other deteriorating agencies may have a like effect and should be gaurded against during processes of construction or reconstruction.

(b) **Strength of guards.**—The strength of guards has frequently been given insufficient consideration in their design and installation. As an instance of this, in a recent discussion among safety engineers the strength of a standard guardrail post of 1.25-inch wrought-iron pipe 42 inches high was questioned. This led to tests of 6 posts of 1.25-inch iron pipe attached to flooring in six different ways, including those most frequently used when installing guardrails.

When the post was fastened to a 2-inch maple floor by a standard cast-iron floor flange with four 2-inch No. 10 wood screws, the screws started out of the floor when a horizontal force of 60 pounds was applied to the post 42 inches above the floor, and the screws pulled completely out with a force of less than 80 pounds.

When the same type of cast-iron floor flange and post was mounted on 4-inch maple flooring with four 3-inch No. 14 wood screws, the flange started when the horizontal force applied to the post 42 inches above the floor reached 90 pounds, and the cast-iron flange broke, freeing the pipe, before the horizontal force had been increased to a value of 120 pounds.

When methods of holding the 1.25-inch pipe post to the floor were used that developed the full strength of the pipe, it took a permanent set when a force of about 125 pounds was applied to it horizontally 42 inches above the floor.

When the 1.25-inch post was supported by slipping it over a 1-inch pipe projecting 6 inches above the floor, the post took a permanent set by bending the 1-inch pipe at about 90 pounds applied horizontally 42 inches above the floor.

A horizontal rail of larger size, 1.5-inch wrought-iron pipe, when supported by posts 8 feet apart took a permanent set when a force of 230 pounds was applied in the center of the span.

(c) **Types of guards.**

(*4*) *Shields or inclosures.*—Guards inside of the guard zone are permitted by rule 114 (*a*) above when these guards are located under definite engineering design. As a general exception to 114 (*a*) above, guards whether or not of definite engineering design may be located within the guard-zone distance specified in column 4 of Table 2 when the guards are of insulating material completely inclosing the live parts and the voltage of the circuit is less than 7,500 volts.

As a second exception to rule 114 (*a*), if the guards are located farther away from the live parts than the radius of the guard zone, in column 4 Table 2, plus 4 inches, then the guards need not extend to the height above the floor specified in column 2, Table 2, but need be only 7.5 feet above the floor.

(*5*) *Insulating covering on conductors or parts.*—As a general exception to rule 114 (*a*) when the voltage of the circuit does not exceed 750 volts in dry places, the insulating covering of the wires may be used in lieu of a guard although it is within the radius of the guard zone. This general exception to rule 114 (*a*) permitting the insulating covering of wires to be used as a guard may be extended, when other forms of guarding are impracticable back of switchboards or in equivalent sheltered locations, to circuits whose voltage exceeds 750 but not 7,500 volts.

(6) *Mats.*—Where mats are used as guards, additional insulating guards may sometimes be necessary. Permanent insulating guards in addition to floor mats should be provided where circumstances require, so that persons can not, while touching certain live parts, at the same time inadvertently come in contact with other live parts or conducting objects or surfaces not insulated from ground.

15. Working Space About Electrical Equipment.

(a) **Where required.**—Crowded machinery with either live or moving parts presents the most hazardous condition in stations. Because of restricted working space and inconvenient access, equipment is liable to suffer from inattention and insufficient cleaning, and consequently to deteriorate rapidly to a condition endangering both the attendant and the continuity of service.

Working spaces about exposed live parts should be made inaccessible to other than authorized attendants by the use of suitable barriers when necessary. This may be accomplished through the supervision of an attendant whose duties include restraining the entrance of unauthorized persons or by fencing or otherwise inclosing the area used as a working space. In any case warning signs should be displayed prohibiting entrance of unauthorized persons.

(b) **Width of working space.**—It is necessary to provide for occasional approach to live parts, such, for instance, as by removal of compartment covers from disconnecting switches. Where live parts are at both sides of a working space, a person can not safely draw away from one side in case of slight shock or accident unless the width is considerable. The spaces specified are minimums and should be increased as much as practicable. In all cases it is recommended that live parts be not exposed at both sides of working spaces. It is recognized that the hazard from exposed live parts at both sides is greatly increased in long passageways. Where switches are ordinarily guarded, but work must be occasionally done about them, as with remotely controlled switches, or where disconnectors and fuses must be occasionally handled, the only feasible safeguard is the provision of thoroughly adequate working spaces so that the person may keep at a suitable distance in making any necessary examination and may freely utilize proper insulating tools in making any needed adjustments.

Instances may occur in existing installations where the specified working space could not be provided. Protection may then be afforded by the use of suitable inclosures or barriers, insulating materials or mats, whichever method is most adaptable to the conditions.

116. Equipment for Work on Live Parts.

Rules 422 A, B, and C state definite methods for work on live parts and clearances to be maintained between workmen and live parts. In order to make it possible for workmen to comply with the operating rules mentioned above it will be necessary to provide in addition to adequate working spaces suitable tools for the work.

117. Hazardous Locations.

(a) **Inclosure of arcing and heating parts.**—Motors and generators having commutators or rings and brushes or other parts which are liable to arc during operation should be kept out of locations where arcing may set fire to inflammable gas or to accumulations of inflammable dust and lint. Where necessarily adjacent to such locations they should be installed in adequately ventilated, separate rooms or compartments or otherwise isolated from the dangerous gas or flyings. If lack of space or other considerations make this impracticable, special casings must be used for such machines, according to the character of the hazard.

Where combustible flyings only exist, it will usually be sufficient to provide a casing of the inclosed type (see definition). For locations where inflammable gas exists in considerable quantities, an explosion-proof casing should be used, as is customary in gaseous coal mines. It should be noted that in some locations, as in battery rooms, hydrogen gas may exist in dangerous quantities near the top of the room, while the lower part of the room is relatively free; whereas in garages the space within a few feet of the floor may contain inflammable gases in dangerous quantities, although the upper portions may be free from such gas. It is best to exclude motors from such rooms, but where they are necessary, type and location must be carefully considered.

In underground stations, subways, and similar locations where inflammable gas is present, it may be necessary to inclose arcing parts in cases which will withstand any explosion that may result from gas contained in them without igniting inflammable gases outside. Cases with carefully screened passages have been developed to meet such conditions.

118. Shielding of Equipment from Deteriorating Agencies.

Any hastening of deterioration of electrical equipment by moisture or uncleanliness means greater danger of breakdown of insulation, that may fail at the point where the attendant is handling it and cause harmful shock, or near him and cause burns or mechanical injuries. The conditions of good contact and cramped surroundings are likely to augment the danger and injury under such circumstances.

The rubber-insulated leads to oil-insulated transformers and switches often deteriorate rapidly and endanger attendants who may come in contact with these leads, relying on their insulating coverings as a guard.

119. Identification.

(a) **Equipment in general.**—The ability readily to identify and trace the connections of equipment, particularly such grouped arrangements as occur commonly at switchboards and in bus chambers, not only facilitates repairs and makes for continuity of service, but safeguards against the danger to workmen from handling live parts in mistaken belief that the parts are disconnected from the source of supply. Many companies recognize this in their practice, sometimes from previous bad experience through incomplete identification. The rules of many commissions and countries dwell on this point. Labeling frequently provides the best means for identifying switchboard circuits. Sometimes code letters or a color scheme is successfully used. The installation rules of the Verband Deutscher Elektrotechniker require very complete diagrams to be kept in convenient locations to assist the other means for identification, and labels are specifically called for at all automatic circuit breakers.

Circuit arrangement should be simple and orderly for safety. A considerable number of conductors, in parallel lines and tagged or labeled, are much safer than a few which are crossed and unlabeled.

Parts which are interchangeable such as some types of switch-compartment doors should not carry the identification mark. In such instances greater hazard is created than if no identification were used. It is evident that care and foresight aid materially in the methods used for identification.

(b) **Generators and motors.**—Individual machines liable to be moved and installed in different locations and for different uses should be provided with a name plate giving important operating data. For rotating equipment it will be necessary to specify the capacity rating, speed, voltage, and when necessary the frequency and condition of operation, such as series or shunt characteristic. It is often desirable to have the power rating given for both continuous and intermittent loads.

Sec. 12. ROTATING EQUIPMENT

120. Speed-Control and Stopping Devices.

(a) **Speed limits for prime movers.**—The importance of automatic speed-limiting devices for certain types of prime movers is well recognized. Failures of rotating parts by overspeed occur more frequently than boiler explosions. With steam turbines and belted water turbines, except certain designs of reaction turbines, such limiting devices are particularly needed. Even reciprocating engines are frequently fitted with extra valves and independent speed-limiting mechanisms. Generators driven by prime movers carry a load that may change suddenly from overload to nearly zero due to the opening of automatic circuit-breakers or fuses. The speed-limit device may, therefore, need to respond quickly, and yet, in cutting off the steam or water supply from the engine or turbine, must not introduce serious likelihood of damage to the feeder piping.

(b) **Stops for rotating equipment.**—Provision of more than one manual control device is often desirable for stopping prime movers or motors, since in emergencies this may save valuable time, especially where the equipment is of considerable extent and much distance might have to be traversed in order to reach a single point of control. Through the use of relay control circuits a single valve or main switch can readily be operated from several points.

Such control circuits must be properly installed and identified. Much care must be taken in the method of identification used, as it is not uncommon for operators in emergencies to shut down the wrong machine. Individual location or proper labels are the best methods of identification.

(c) **Speed limit for motors.**—Separately excited direct-current motors are particularly liable to "run away," since their field-excitation current may be greatly reduced while the armature current still is maintained. To a less degree series motors, A. C. motors of series characteristics, motor-generators operating in parallel, or feeding storage batteries, and rotary converters are also subject to "runaways." Where direct-connected to mechanical load, dangerous overspeed is not likely to occur, but where belt-connected or having only a generator load, which may be readily lost by the opening of automatic circuit-breakers, the danger of overspeeding is considerable. Centrifugal devices which, at overspeeds, actuate trip devices for opening the source of energy supply are most often utilized. An audible warning signal that sounds automatically as soon as the speed exceeds its safe limit is also advisable.

(d) **Low-voltage or undervoltage protection.**—A most common motor protective device is one against undervoltage. Two forms of this protection have been recognized, namely, low-voltage protection and low-voltage release.

Low-voltage protection provides for the disconnection of the motor from the source of supply upon serious reduction of voltage and does not permit the motor to start again on the return of power, but depends on a manual starting operation to restart the motor when the normal voltage is restored. All motors employed or arranged so that the unexpected starting of the motor will produce a hazard should be equipped with low-voltage protection. Where the opening of a circuit might cause a hazard, as with circuits supplying exciters or condenser-pump motors, low-voltage protection is not desirable.

Low-voltage release provides for the disconnection of the motor from the line upon serious reduction of voltage, but permits it to restart immediately when normal line voltage is restored.

(e) **Adjustable-speed motors.**—With direct-current motors having speed adjustment through field control, dangerously weak fields must be avoided to limit dangerous speed, especially when the load is not direct-connected to the motor or consists of generators. Release coils, whether placed on starting rheostats or elsewhere, through which the field circuit passes, are used to prevent loss of fields during operation. In some cases centrifugal speed-limiting devices are installed.

Devices, such as are considered in the foregoing paragraphs, should be tested at frequent intervals to insure their proper operation in case of necessity.

(f) **Protection of control circuits.**—The relative importance of electrical circuits controlling stopping devices, together with the natural frailty of the comparatively small conductors employed, make the use of conduit or other mechanical protection essential to assure reliability.

The use of normally closed circuits assures that any chance open-circuit will immediately give evidence of its esixtence through lamps or bells connected in the circuit. With open circuits a break in the circuit may not be discovered until in an emergency the control may be found inoperative. Where, as with motor-operated switches or valves, the control circuits must be normally open, or where other conditions make the use of open circuits desirable, it will be necessary to depend on the mechanical protection of the circuit for its maintenance in operative condition.

121. Guards for Live Parts.

(a) **Guards on rotating equipment.**—For live parts on low-voltage machines guarding is usually sufficiently secured by the provision of insulating mats, which prevent persons from standing on grounded parts while touching live parts. Mats may be of wood, held together by wood pins, or may be of linoleum or rubber. The material and construction should be suitable for the prevailing conditions. If subject to moisture or to accumulation of conducting dust, flyings, or chips, mats must provide surfaces minimizing the hazards from these sources. With higher-voltage machines it is necessary to guard the live parts themselves by suitable inclosures or barriers.

It is impracticable to guard some live parts of rotating machinery, such as commutators, brushes, and slip rings, that require attention under operating conditions, more completely than is afforded by the frames of the machines. In some cases it may be advisable to install insulating shields to prevent attendants from inadvertently touching at the same time live parts and adjacent grounded parts. In some instances the safety of attendants may be increased by insulating frames of generators from ground, when they are surrounded by nonconducting flooring and supply grounded circuits.

(b) **Access to live parts.**—Large machines requiring examination or adjustment of live parts during operation are generally designed to permit access to such live parts by means of platforms or steps with handrails. However, a machine which would ordinarily have its live parts accessible may be installed so as to render these parts inaccessible. Serious accidents may then occur by operators making use of the curved surfaces of machine frames as a means of accessibility to live parts. To avoid this, platforms should be erected or rounded surfaces made flat to afford substantial footing.

(c) **Frame switches.**—See discussion of rule 169.

(d) **Arcing shields.**—Manufacturers of rotary converters have devoted considerable time and study to flash overs on large commutators. Opinion varies as to methods to be used in obviating these flash overs. Arcing shields or barriers aid materially in the protection of the operator. It is recommended that in order to protect the eye from the intense light of the arc and from ultra-violet rays, goggles of approved type be available. Another essential is plenty of working space. Many operators believe that guard railings should not be used, as one essential condition of work performed on or about such machines is ready and quick exit.

Experience with 25-cycle rotaries, 250 volts on the direct-current side, with neutral grounded, indicates that they are both sufficiently reliable and free from violent commutator flash overs to justify their exemption from the requirement of special arcing shields.

122. Grounding Machine Frames.

(a) **Grounding machine frames.**—Machine frames necessarily operated ungrounded should be considered as alive, so far as concerns danger to persons touching or standing on grounded surfaces in the vicinity. Insulating mats or platforms are therefore necessary about such machines, since their frames may become alive through leakage at any time.

Where generators supply current at more than 300 volts to grounded circuits, such as street-railway circuits, grounding the frames may be omitted to insure greater reliability of service and increased safety to attendants. In case the frames of such generators were grounded, an insulation failure within the machine would be more liable to result in burnouts sufficiently severe to jeopardize continuity of service from the station and subject the attendants to severe emergency conditions. Also, the extensive grounded surfaces presented by the machine frames so near exposed live parts of the machine, increase hazard to attendants performing necessary adjustments and maintenance during operation.

(b) **Coupled machines.**—Machines coupled together offer the same danger to persons, although to a less degree, even where insulating mats are provided, since persons touching both frames at a time may become part of a circuit, unless both frames are held at the same potential by grounding or bonding together.

(c) **Auxiliaries.**—Exciters for machines with ungrounded frames are subject to the potential of those machines on account of possible leakage to the frames. If the principal machine voltage be 1,200 or 2,400 volts to ground (as with ungrounded frames of high-voltage, direct-current railway generators), the exciter frame and circuit may be very dangerous to handle. The danger may, however, be minimized by identifying and guarding both the exciter frame and circuit as 1,200 or 2,400 volt equipment, as the case may be, or by grounding the exciter frame and circuit. Grounding of the exciter frame and circuit may be objectionable for the same reason that led to the absence of a ground connection to the frame of the principal machine. This thoroughly illustrates the difficulties and complications (sometimes far reaching) that may be entailed by omitting ground connections from exposed cases and frames of equipment operating at high voltages.

123. Terminal Bases and Bushings.

(a) **Terminal bases.**—When terminal bases are used to facilitate connections of leads or for mounting switches, they should be of nonabsorptive, noncombustible material, such as slate, marble, porcelain, or composition material. These bases are exposed to the action of oil and are liable to overheating from poor contacts.

(b) **Bushings.**—The insulation of leads when passing through the frames of motors and generators should be protected from mechanical injury and deteriorating influence of oils by suitable bushings. Where inclosed terminal boxes are provided, this protection is not necessary except that the insulation of the leads is preferably reinforced at this point of hazard by suitable composition or rubber bushings.

124. Deteriorating Agencies.

(a) **Protection required.**—See discussion of rules 118, 123, and 125 (*b*).

(b) **Grounding.**—See discussion of rule 113 (*b*).

125. Motors.

(a) **Control.**—Starting apparatus should preferably be located in sight of the motor it controls, so that the attendant will quickly notice anything wrong with the motor during starting and promptly open the circuit, and so that he can see another attendant who may be adjusting or inspecting the motor or the driven machine.

If the starting of the motor can be caused automatically, or if the motor and all driven machinery is not in plain sight from the starter, it will be necessary to provide means for positively preventing the unexpected starting of the motor.

(b) **Motors in hazardous locations.**—Commutator or slip-ring motors and motor switches where sparking may occur, and rheostats at which high temperatures may occur, should preferably be installed in a separate ventilated room large enough for attendant and auxiliary apparatus.

Dust has an appreciable deteriorating influence on motors by wearing the bearings, clogging the cooling air spaces, and occasionally by a sand-blast action on exposed insulation. Because of the rapid depreciation of a protective boxing, its obstruction to dissipation of heat (even if provided with gauze-covered or glazed windows), and its interference with maintenance and inspection, separation from the dusty atmosphere by roomy inclosures, or the use of an inclosed type of motor is recommended.

Sec. 13. STORAGE BATTERIES

130. Isolation.

The danger from personal contact is increased over that in other station rooms by the presence of electrolyte and the resulting decreased contact resistance. The danger from sparks in the inflammable gas given off by storage batteries in charging is also serious, especially in rooms with low ceilings. Injury to insulation of other equipment by acid spray also is liable to occur where the battery is not isolated from such other equipment.

For these reasons battery equipment should be made inaccessible, except to qualified persons, and placed in a room or compartment away from other equipment, if its size permits giving off of inflammable gas or spray in considerable amounts.

131. Ventilation.

With large battery equipment, especially in comparatively small rooms, special ventilation by fans may be necessary to reduce sufficiently the inflammable gas accumulations. Pockets in ceiling spaces above door and window openings should be avoided.

In order to secure adequate safety, hydrogen content must be maintained below 2 per cent by volume. When hydrogen content reaches the neighborhood of 4 per cent by volume, an explosive mixture exists.

In addition to hydrogen gas, the air from a battery room carries with it sulphuric acid spray, small quantities of which have a rapidly destructive effect on both the insulation and metallic parts of electrical apparatus. The ventilating system should therefore be designed so as to carry air from the storage battery room directly to points outside the building. For the same reason it would be well to exercise care in designing the ventilating system.

Covers or guards arranged to catch the electrolyte spray and return it to the cell from which it came are readily devised and applied. Sometimes a beveled edge to each cell is helpful. Sometimes glass plates or other covers placed above the elements prevent the mechanical throwing out of electrolyte, even during violent gassing.

132. Suitable Supports and Floors.

A separate insulating support for each cell prevents current leakage along surfaces from one cell to another that might result in arcing or making adjacent floors alive. Drainage of floors also reduces the danger of shock and retards deterioration of battery and building alike.

A supply of fresh water, raised entrance-door sills, and acid-resisting floors, such as vitrified brick set in pitch, are indications of good design where large battery rooms are installed. Wooden floors are not satisfactory.

Structural steel and other metallic systems under the flooring of battery rooms should be protected from the electrolyte, as by sheet lead laid in such a manner as to interrupt capillary communication between the floor and the steel. Steel frames or other metallic fixtures exposed inside the battery room should be protected from the destructive action of acid spray by acid-proof paint. Copper, brass, and iron should be coated with a thin layer of lead.

133. Guarding Live Parts in Battery Rooms.

(a) Separation of parts of more than 150 volts.—Some batteries are badly arranged through having those cells adjacent between which the highest voltage (that of the entire battery) exists. This can be obviated by proper cell connections, and the danger to attendants and to service continuity will be correspondingly reduced.

(b) Precautions against parts of more than 150 volts.—Where cell connections or battery conductors are necessarily carried beyond the edges of cells, the danger of personal contact may be avoided by provision of suitable inclosing or barrier guards for such live parts, and this should particularly be done where the voltage exceeds 150 to ground.

134. Illumination.

In order to avoid danger of explosion, all flame devices for illumination ought to be kept out of battery rooms. Even incandescent electric lamps should be in keyless sockets, and as the brass shells of sockets, both exterior and screw shells, are subject to corrosion by the acid spray, vapor-proof globes are recommended. Switches also should be placed in vapor-proof inclosures or outside of the room.

135. Acid-Resistive Coverings.

The corrosion of cell connections may produce arcing, and thus be a possible cause of explosions or short-circuits. Choice of suitable metal or application of protective coatings will avoid corrosion, even where acid spray collects on surfaces.

Sec. 14. TRANSFORMERS, INDUCTION REGULATORS, RHEOSTATS, GROUND DETECTORS, AND SIMILAR EQUIPMENT

140. Current-Transformer Secondary Circuits.

(a) **Short-circuiting.**—The opening of a current-transformer secondary may result in breaking down the insulation; in any event it may cause serious arcing and danger at the point of opening. If suitable short-circuiting devices are provided, chance openings are less likely to occur while instruments are being removed or replaced. Even where relays only are supplied a substantial short-circuiting device need not be considered a probable cause for making the relay inoperative, although, of course, the inoperation of the relay would not be indicated, as would that of a meter were the latter short-circuited by such a device.

(b) **Protection when of more than 7,500 volts.**—All such secondary circuits should be installed so as not to be subject to opening by mechanical disturbance, since the conductors are usually small and consequently frail; where in exposed locations, conduit provides the best means of protection.

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141. Grounding Low-Voltage Circuits of Instrument Transformers.

In some cases, as with voltage-regulator control circuits, proper and reliable operation necessitates that the entire low-voltage circuit be free from a ground connection. This circuit, if so left ungrounded, may at any time, without warning, take up a high voltage by reason of leakage or induction. For this reason it should be run in all respects as required for high-voltage circuits and be clearly distinguished by suitable markings from other low-voltage circuits with which it may be associated.

142. Grounding Transformer Cases.

Transformer cases in stations where so many other grounded surfaces usually exist should be themselves grounded to protect attendants. If, however, they are marked as high-voltage parts and guarded by insulating mats or barriers where these would be required for current-carrying parts at the voltage concerned, the grounding requirement may be waived.

Where inflammable gas is present, the grounding is always necessary to prevent explosions due to arcs from the case or frame to supporting surfaces.

143. Location and Arrangement of Transformers.

Where transformers are installed with utilization equipment, they are frequently on poles in connection with yard wiring and then should comply, of course, with the rules for overhead lines as to clearance from buildings and nonobstruction of climbing space, etc. When placed against walls of buildings, they should be sufficiently distant from adjacent window openings to assure that burning oil will not cause fire hazard and that persons in or on buildings will not inadvertently come in contact with the frame or high-voltage leads.

Where placed inside buildings containing other equipment, transformers may be placed in transformer vaults, and these will usually be particularly necessary in buildings not used solely for station purposes where the amount of oil in the transformer casing is considerable or where the voltage much exceeds 750. The wiring and spaces within the vault should comply with the rules for stations or for underground construction, and the interior should, of course, be inaccessible to any but authorized persons. Where the entire transformer installation is of less than 750 volts, it may sometimes be placed in open factory rooms with other machinery, although where oil-insulated devices are used, which contain oil in considerable amounts, the location in a separate room is usually desirable.

Approved vault construction is specified by the National Electrical (Fire) Code and strongly recommended for industrial substations. Where the transformers operate at more than 750 volts, high-voltage parts may be entirely inclosed or otherwise guarded so as to be inaccessible to any but the qualified operators, but without inclosure necessarily in a separate room if such other guarding can be made as effective and if the amount of oil used for insulation does not necessitate the use of a separate room to prevent excessive fire hazard.

Outdoor installations, such as substations or switch stations, quite frequently attract persons, especially children, into their danger zone. For this reason such stations should be inaccessible. Barriers, such as high fences, are effective. In addition, danger and warning signs aid materially in accomplishing this isolation from all excepting the qualified operators.

144. Resistance Devices.

Rheostats and other resistance devices should always be considered as sources of heat, liable to become red hot, and from which drops of molten metal or heated metal may fall or become spattered to some distance. The fire and personal hazard can only be avoided by installing rheostats with this possibility in mind.

Resistance wires or grids are designed to radiate or dissipate heat. If they are covered with a blanket of dust, this dissipation is greatly interferred with, possibly resulting in deteriorating or melting temperatures. Rheostats in dusty locations should therefore be mounted in noncombustible cabinets or equipped with dust-proof face plates to protect the wires or grids from the accumulation of dust.

Resistors in general, and particularly those handling large currents, should be placed where a free circulation of clean air is available, and preferably not in a location adjacent to the units they control.

Frames should be of fireproof material mounted on noncombustible insulating supports. The frame should be grounded through a fuse, which may be easily inspected to determine breakdowns of insulating supports of the grids or other insulating material composing the rheostat.

Rheostats should be placed in such a position as to avoid the delivery of heat to either the leads or dial-switch heads, thus prolonging the life of the leads and reducing the troubles with switch heads which occur when forced to operate at temperatures above normal room temperatures.

145. Ground Detectors.

When a circuit which is normally grounded at the station, such as a three-phase star-connected grounded-neutral circuit is accidently grounded at a point on the line by a wire coming down, the circuit breaker at the station will probably automatically open and clear the line. Any possibility of contact by persons with a live wire is thus removed. When the circuit is not normally grounded, such an accident will always produce a hazard to persons. It may also cause injurious surges and is, in general, a serious operating condition on account of the increased dielectric stress in the station apparatus and the possible interruptions to service. The instruments which are usually installed on switchboards, such as voltmeters, wattmeters, and ammeters, will not indicate an unbalance or disturbance caused by a wire coming down and interrupting the continuity of the circuit unless the break is near the station and considerable power is being delivered by the circuit.

For this reason it is necessary to install means for ground detection to give an indication of this unusual and dangerous condition. Since a ground on any one circuit will ground the entire bus section feeding that circuit, it will be necessary to install but one detector on such a bus section. Since ground detectors bring the ground in close proximity to the conductors of the circuits, the detector will be the first instrument to be affected by outside distrubances, such as lightning surges or crosses with other lines. For this reason it is probably preferable to have the detector normally disconnected and only employed at stated and regular intervals, as when the station operator reads the meters and performs other duties of like nature. Otherwise the detector may be put out of service just when it is most needed. This has occurred so frequently as to discredit detectors.

There are several types of ground detectors on the market, and several methods are employed by different operating companies, most of which have their good points and may be considered reliable if used as intended. The most familiar is probably the electrostatic type. The potential transformer equipped with resistors and lamp or other indicating device is used quite widely.

One utility reports employing the usual switch hook having a metal head on the end of a wooden or insulating handle of proper dimensions for the voltage worked on. This hook is presented to the exposed live terminal or other portion of the conductors of the circuit and the lack of a ground is indicated by the charging current flowing to the metal hook. Inversely the lack of this spark will indicate a ground on the conductor being investigated. Other types of detectors which have been considered are the vacuum tube and the electroscope. The former glows when presented to an ungrounded conductor while the latter gives the familiar electroscopic effect or repulsion action between two bodies charged to the same potential.

For direct-current systems the ordinary voltmeter is perhaps more satsifactory and more readily operated than the detectors employed for alternating-current use, and indicates the nature of the ground to some extent.

In addition to a visual indication, an automatic audible alarm is suggested for particularly important cases, or where there is no continuous supervision of the circuit involved.

Sec. 15. CONDUCTORS

150. Electrical Protection.

(a) **Fuses required.**—In hot locations, slow-burning insulating covering or omission of insulating covering will be necessary to make conductors suitable for the conditions. In very damp locations a lead or alloy metal sheath may be necessary for wires with insulating covering.

For the best protection of persons in the vicinity, or those engaged in operating switches on circuits, conductors of the circuit need automatic protection against currents large enough to exert disruptive stresses, to cause serious arcing or short-circuits at switches, to melt connections or the conductors themselves, or even to seriously damage insulation. Many fatalities have been due to large-capacity short-circuits in feeders unprotected by automatic circuit-breakers.

(b) **Fuses in grounded conductors.**—A grounded conductor should never be interrupted nor disconnected from ground by the opening of an automatic circuit-breaker or fuse, since this would permit part of the circuit to lose its ground connection and possibly assume the highest voltage of any circuit to which it is exposed or from which leakage might occur.

(c) **Circuits exposed to higher voltages.**—The two chief reasons for protection of exposed circuits are to avoid danger from (1) leaks through failure in transformer insulation and (2) accidental contacts or connections with higher-voltage wires. Grounding is universally accepted as the safest method to be used for low voltage, but some engineers object to grounding circuits of more than 150 volts, and guarding or isolation may be employed as alternatives.

The general safety of electrical circuits of more than 300 volts would often be increased if their complete insulation from ground could be maintained and no exposure to circuits of higher voltage existed. It is usually impracticable, however, to maintain complete insulation from ground over extensive circuits, and exposure to circuits of higher voltage is usually present. This leads to the conclusion that the safest general plan is to effectively ground circuits even though this will result in conductors normally operating at more than 150 volts to ground.

151. Precaution Against Mechanical and Thermal Damage.

(a) **Protection against injury.**—Usually the insulating covering of a conductor is not designed to be also a mechanical protection. Its function is to provide insulation, and it should therefore be protected against any mechanical injury, so that its value as a dielectric will remain undiminished. Even if surrounded with an effective insulating covering, a conductor may be dangerous through the existence of a charge on its exterior surface, especially where flame-proofing material is used that is to a degree conducting and where the voltage of the conductor is relatively high.

(b) **Flame-proofing.**—Where conductors are necessarily grouped rather closely, the danger from fires spreading becomes considerable, unless the insulation is incapable of supporting combustion. This applies more particularly to conductors connected with circuits whose overload protection and energy capacity make possible a strong arc of sufficient volume to ignite quickly near-by combustible material. The flame-proofing is primarily to protect conductors against near-by conductors involved in electrical fires rather than an attempt to reduce the concentration of inflammable material involved.

For large cables Portland cement plaster, at least 0.5 inch thick, over a wrapping of rope, has been found effective.

Asbestos sleeves, taping, or impregnation with flame-proofing compounds, are methods employed for smaller or lower voltage conductors.

Where connected to bare terminals, flame-proofing compounds or braids such as are at all conducting must, of course, be stripped away from the bare terminal.

(c) **Protection against contact.**—In case of severe overloads, adjacent conductors have been seriously damaged by the repulsive effect of their magnetic fields.

(d) **Conductors between generators and outside lines.**—Large conductors from generators to outside lines, if placed on approved insulators, should be kept so rigidly in place that the can not come in contact. Where they pass through floors or fire walls they should be carried through individual openings in approved insulating tubes or their equivalent and not through a common open space.

When cables, conduits, tile, or other fireproof ducts are used, care should be taken that moisture can not destroy their insulation. Condensation alone is sometimes sufficient to cause rapid deterioration, and for this reason principally, metal-sheathed cables are strongly recommended provided that when installed the sheaths are permanently grounded. Even with such construction moisture is liable to affect them, especially at points where the conductors leave the cables. Potheads or some equivalent method not only protect against moisture deterioration but prevent mechanical injury.

(e) **High temperatures.**—Insulated conductors exposed to excessive temperatures sometimes need an additional protection. The standards of the American Institute of Electrical Engineers specify the maximum safe limiting temperatures for various insulations. It is advisable to keep within these specified limits. Dangerous temperature rises can be immediately announced in a supervising office by means of an automatic audible signal installed for the purpose.

152. Isolation by Elevation.

Conductors run at elevations well above the heads of persons are relatively free from danger of mechanical injury to insulation and offer much less hazard to persons in the vicinity. Adequate elevation may be regarded as providing a protection to persons equivalent to actual guarding by casing or armor.

153. Guarding Conductors.

(a) **Metal-sheathed cable outlets of more than 750 volts.**—Metal-sheathed cable affords adequate protection when properly installed. In dry locations the metal sheath need not be continuous over splices if suitably bonded electrically across the splice. The bond should have a current capacity not less than a No. 6 A. W. G. copper wire. In damp locations the sheath must not be interrupted.

Potheads or equivalent methods to protect the cable at the ends or outlets from moisture, mechanical injury, and electrical strains are indications of safe construction.

(b) **Form of guards.**—It is not always practicable or convenient to isolate insulated conductors of more than 750 volts or open bare conductors of more than 300 volts to ground.

Alternatives, such as inclosing partitions, suitable barrier guards, insulating platforms, mats, or covers, may also be used. At the same time that the liability of accidental contact is lessened, short-circuits by conducting tools or other objects either in the hands of workmen or by falling, etc., will be minimized.

Conduit, metal sheathing, or other fire-resistive ducts and runways constitute suitable protection for conductors, both to prevent mechanical injury and to prevent accidental contacts. Fiber ducts, although not strictly fire resistive, are included among suitable ducts. If a number are grouped together, some further fireproofing is advisable.

For voltages exceeding 750, to protect persons from contact with conductors, an exterior grounded metal sheath or conduit is usually best. In damp places such protection is particularly desirable as against reliance on insulating coverings and ducts. Fiber conduit in dry locations provides a substantial and fairly reliable insulation and is used to some extent with insulated cable having no metal sheath. This practice should, of course, be confined to thoroughly dry locations, since moisture is readily absorbed and the fiber duct no longer provides reliable protection for unsheathed conductors.

154. Guarding in Hazardous Locations.

(a) **Conduit or metal sheath.**—The slightest arcing at bad joints of conduit may be serious in locations where inflammable gas is present. It is necessary that the conduit should be thoroughly tight to prevent entrance of such gas, which may be set afire at any point where arcing might occur because of poor joints of the conduit or at a point where the insulation is defective between one of the conductors and the conduit itself.

(b) **Insulating supports.**—In some very wet places conductors, if out of reach and so not subject to damage, are very well protected from leakage to surrounding surfaces by installation on insulators providing long leakage distances. If conductors are within reach, persons in the vicinity are, of course, endangered.

155. Taping Ends and Joints.

Joints of insulated conductors unless guarded should be protected with an insulation equal to that on the conductor itself. Good practice also requires that the joints be made mechanically and electrically secure without solder and then soldered, or that some form of approved connector be used. The ends of conductors should also be taped unless some form of insulating nipple, fitting the end of the conductor, is used.

Sec. 16. FUSES, CIRCUIT-BREAKERS, SWITCHES, AND CONTROLLERS

160. Accessible and Indicating.

(a) **Arrangement.**—Switches and other control or protective equipment should be very convenient to the operator, as no other part of the station installation is so often used during operation and in emergencies. Accidental operation may cause serious danger to service, to operators, and to equipment, and should be prevented as far as possible by suitable design and arrangement. Marking, in addition to orderly arrangement, may be advisable to show the function of switches or fuses.

(b) **Accidental closing.**—It is usually practicable to install single-throw knife switches to open downward. Double-throw switches should be provided with a proper latch or stop block on one or both sides to prevent the switch being closed by gravity, unless they are mounted for horizontal throw.

161. Oil Switches.

The wide and varied application of oil switches has resulted in many types of construction and design. In general, oil switches of more than 7,500 volts are designed for remote control. Oil switches of more than 7,500 volts have been designed for mounting on the rear of switchboards, but this is not good practice and should be discontinued.

Failure of a switch to open a short-circuit may result in the explosion of the switch tank, permitting burning oil to escape. The scattering of burning oil may injure persons. The resulting fire may do considerable damage to other apparatus. It is for these reasons that the desirability of isolation, fireproof surroundings, or fireproof inclosure for such apparatus should be fully appreciated.

162. Where Switches Are Required.

The installation of a suitable switch provides means for disconnecting equipment and circuits entirely from the source of supply. Such precaution may be necessary to safeguard workmen on equipment, or in emergency to prevent further injury to a person who has been caught in moving machinery or has come in contact with live parts controlled by the switches.

It is, however, unnecessary to place switches between two pieces of equipment always operated as a single unit, since persons will not be working on such equipment without special precautions unless both parts are disconnected from the source of energy.

The disconnection of conductors should be as near to the source of energy as practicable, but the use of conductor leads of moderate length between a generator and a suitable switch is considered as complying with the rule.

163. Switches or Other Grounding Devices.

Maintenance or repair work on electrical equipment that will bring attendants in contact with or near to exposed conductors, although disconnected from the circuit, should not be done until these conductors are effectively grounded, particularly if the equipment operates at high voltage. It is advisable to install a permanent means to facilitate the protection assured by effectively grounding disconnected conductors of equipment that will be periodically or frequently disconnected and approached by attendants. A grounding means at the station may also be applied to outgoing lines when disconnected for work on them, although portable grounding and short-circuiting devices will be none the less necessary with the linemen on each side of the point worked on.

In new installations, permanent means for grounding should always be installed, but for existing installations, where it would not be practicable for economic or engineering reasons to install this equipment, portable grounding devices may be used. A grounded copper chain attached to the end of a wooden pole is an example of devices to serve this purpose.

164. Capacity of Switches and Disconnectors.

(a) **Suitability.**—The capacity of a switch, when it must be operated under load, should be proportioned to the load that it is likely to be required to interrupt. If in addition to the switch no fuses or automatic circuit-breakers are in the circuit, and the design of the system does not provide other means to closely limit the current, the switch should, in general, be also an automatic circuit-breaker and arranged to operate before the current rises unduly, or else the switch should be considered and identified as a disconnector. It will be advantageous to provide a meter indicating the load carried by such a switch, so that the operator will not accidentally open it under loads greater than those which it may safely interrupt. In some cases it has been found advantageous to arrange an automatic lock on switches not capable of interrupting currents which they may be called upon to carry, so arranged that the latch is held in place by a magnetic field depending upon the current flow through the switch, thus preventing accidental opening.

Where switches are to be operated only as disconnectors to open circuits under no load, they need only the capable of carrying the full load current of the circuit and should be suitably identified as disconnectors. It is important where a number of disconnectors are placed together that they be carefully distinguished by suitable markings, so that the wrong disconnector will not be accidentally opened.

(b) **Locking.**—Except air-break switches near the equipment controlled, all switches are likely to be operated without full knowledge of the load condition of the equipment, and if closed while persons are working on the controlled equipment may cause serious hazard. In such cases arrangements should be provided so that switches can be locked or blocked in the open position.

Mechanical forces due to the magnetic fields around conductors in bus structures have opened disconnectors, with a resultant damage to the equipment, injury to operators, and interruption of service. Locking disconnectors in the closed position is therefore strongly recommended. The disconnectors and the supporting parts must be strong enough to resist these mechanical forces. There is at least one case on record in which locked disconnectors have been torn from their supports and the insulators destroyed.

(c) **Air break.**—Air-break switches may usually be considered free from leakage, but this is by no means true of oil-break switches. Leakage across the gap of oil-break switches may be sufficient to cause dangerous shocks to persons in contact with circuits supplied through them, and suitable disconnectors should be used to obviate this trouble. Switches connecting busses, or otherwise so located that they can be made alive from both sides, should usually be protected by air-break disconnectors at each side, and this is common in good practice.

(d) **Alignment.**—Knife switches having such poor alignment that they can not be closed with a single unhestitating motion not only create personal hazard from possible sparking or arcing but may interrupt the continuity of service.

165. When Fuses or Automatic Circuit-Breakers Are Required.

Except where greater hazard might be caused by the opening of circuits automatically than by overloads and short-circuits, the protection of fuses or automatic circuit-breakers should always be afforded to equipment and circuits. With certain types of circuits, however, the use of fuses or automatic circuit-breakers operating on overloads is relatively unnecessary. Resistors or reactors or suitable regulators might satisfactorily limit the possible currents in circuits from generators or batteries. Series arc circuits supplied from special generators are examples of circuits limited by their design to a certain maximum current.

(1) Although overloads are imposed upon rotary converters or motor-generators from the load side, it is considered better practice to interrupt the supply circuit rather than the conductors feeding the load, in case of dangerous overload. Synchronous converters will flash upon opening of a direct-current circuit-breaker at currents which are satisfactorily commutated with the direct-current circuit closed. This is one reason for not opening the direct-current side until after the alternating-current side has been opened. Direct-current

circuit-breakers may well be placed on individual feeder circuits of a group supplied from such a machine, so that the overload upon an individual feeder is interrupted automatically. It will then seldom be necessary to cut current off entirely from the machine. In some modern automatic railway substations no provision is made for opening outgoing feeder circuits on overload, the distribution system being operated with the substation as a single unit.

When a storage battery is connected in parallel to the direct-current side of such a machine and the main circuit-breaker is on the alternating-current side, some measures are necessary to prevent the battery from feeding back into the machine upon failure of power. This result may be accomplished by the use of a reverse-current or reverse-power relay. Such equipment can not be used, however, when it is desired to have power flow back to the alternating-current side, as in the regenerative control of railway trains.

(2) The importance of omitting fuses or automatic circuit-breakers on grounded conductors is very evident. The protective value and effectiveness of the ground connections to all circuits and apparatus should not be interfered with under any condition.

(3) Excitation circuits for generators or motors should not be capable of automatic interruption at any point. The hazards produced by such an interruption would be very great under some conditions.

(4) Automatic circuit-breakers in the leads of alternating-current generators would produce greater hazards than their absence, but manually operated breakers are desirable to isolate a machine when it is necessary to make repairs. The sudden interruption of an overload might cause the machine to run away or attain a dangerously high speed. On the other hand, with the present tendency of very large generating units and stations and the concentration of large

amounts of power at one place, it is evident that short-circuits or heavy overloads may give rise to very destructive effects. As a substitute for the protective value of automatic circuit-breakers it is customary to install current-limiting devices in the leads of alternating-current generators in the form of reactors. These may be placed wherever experience has demonstrated that they are most needed; in the leads, between bus-bar sections, or in the feeders. The tendency is toward changing the design of the generator to increase its inherent reactance to a sufficient degree to provide the necessary protection for the generator itself.

(5) When two or more pieces of electrical supply equipment are electrically connected together the opening of this connection may throw a destructive overload or underload, depending on conditions, on either one or more of various connected pieces of apparatus. Automatic disconnecting devices should not, therefore, be employed under these conditions. An example is generators operating in parallel.

(6) Where one or more stations supplies an interconnected, three-wire low-voltage distributing system, the insertion of automatic protection on each of the various feeders connected to this system might produce a very serious operating condition which in some cases would be extremely difficult to handle.

(7) The secondary current of a series transformer is limited by the current in the primary, and no automatic overload protective device is needed. The interruption of the secondary causes an abnormal voltage in it and an abnormal reactance in the primary circuit, and, hence, would be objectionable.

(8) Where theater emergency lighting, elevators, hospital operating-room lamps, and similar vitally necessary service may be dependent on the supply of current, the danger to consumers may be more serious than any hazard which may

be caused by overloads on the circuits. Automatic circuit-breakers are, therefore, not desirable in such cases except on individual circuits.

166. Disconnection of Fuses before Handling.

Except for fuses at low voltages the danger from shock in removing them from exposed live clips or other contacts is considerable. With fairly large fuses even at low voltage the hazard of receiving burns while replacing a fuse in a live clip through the blowing of the fuse by short circuits beyond it is serious. The best protection is afforded by such an arrangement of fuses that they are inaccessible while their current-carrying parts are alive, and this is accomplished in good modern practice by the inclosure of the fuses, so that the opening of the inclosure disconnects the fuses from the source of energy. While generally adaptable to industrial uses, such an arrangement may be impracticable for certain parts of station equipment where quick access is a very great factor to minimize service interruptions. In such cases the second means of protection will usually be preferable if the fuse has to be handled frequently, since the operation of a switch in series is much more quickly and safely performed than the removal of a fuse from exposed live terminals either by an insulating handle or similar portable appliance.

167. Arcing or Suddenly Moving Parts.

(a) **Protection from burns.**—For station operation it is not always practicable to inclose fuses or circuit-breakers in cabinets as in utilization equipment. Severe burns and eye flashes are not uncommon and must be considered when handling such appliances. The intensity of the arc alone may cause a severe eye injury. Proper location or shielding tends to overcome such hazards.

(b) **Protection against moving parts.**—See discussion of rule 112.

168. Grounding Noncurrent-Carrying Metal Parts.

Since switches are usually placed where they are most conveniently accessible, their cases and operating handles will usually be located so as to expose the operator and others to injury if accidentally alive. Since operation should be thoroughly safe, so that service may not be delayed or other persons endangered by the hesitation of the operator to handle the switch, exposed metal parts not intended to be alive should be thoroughly grounded.

169. Guarding Live Parts of Switches, Fuses, and Automatic Circuit-Breakers.

The best safeguard from contact with the live parts of a switch is probably that provided by remote-control operation of a switch. The provision of a casing in which all live parts of a switch are inclosed is also an effective safeguard. To be suitable, the switch and casings must be arranged so that the switch can be operated without removal of covers or otherwise opening the casing. In addition to better safeguarding the operator, such an arrangement prevents any delay in operation caused by the necessity for opening the switch case in order to operate the switch.

Control circuits or devices, in addition to performing their function, should indicate in some practicable manner whether the switches they control are open or closed.

For low voltages sufficient protection may be provided by the use on switches of insulating handles, together with a disk or other barrier guard so attached to the handle that the hands are reasonable protected against slipping into contact with the live parts and to some degree against burns from arcing at the switch contacts. With large switches, however, even at low voltages, remote control or use of a casing is recommended.

The most common cause of shocks (contact with live parts while the person is standing on surfaces more or less grounded) is removed by the use of suitable insulating floors. Unless a switch is inclosed during operation, insulating floor protection should be provided where switches operate at more than 300 volts to ground.

Even when isolated by elevation, disconnectors are sometimes provided with barriers to protect against possible short-circuits due to arcing. Whenever barriers are used they may fail in their purpose unless extending beyond all possibly live parts. Disconnectors which are or may become alive from either end should have barriers sufficient to protect the blade (when open) in any position.

Sec. 17. SWITCHBOARDS

170. Location and Accessibility.

(a) **General location.**—Neighboring machines should never encroach on the working space, and since rapid control is necessary, the working space at the operating platform should be very liberal and permit the operator to give full attention to his special duties on the switchboard itself, rather than to his danger from neighboring equipment.

(b) **Spaces about boards.**—Boards should not be closed in except by screens or wire nettings, interferring as little as may be with visibility and light from outside, and affording ample working space within. Such spaces should not be used for locker rooms, storage of oil cans, waste, etc., thus limiting the required working space and possibly blocking the exits.

(c) **Accessibility.**—It is urged that liberal working space be maintained for both front and rear of switchboards. When ample room is provided, men not only do better work, but the liability of their dropping tools or otherwise causing short-circuits which may cause personal injury or damage to apparatus is minimized. Boards should never be built up to the ceiling, but rather a space of about 2 feet left if the ceiling is composed of combustible material.

(d) **Arrangements.**—It should be possible for all switches to be operated, all instruments read, and relays adjusted without bringing the hand or head close to live parts or causing the operator to take a position above live parts or to climb ladders or to take other positions from which he is liable to slip or fall against live parts.

171. Material and Illumination.

(a) **Material.**—Materials used for switchboards are slate, soapstone, or marble, generally treated either to prevent the absorption of moisture, oils, etc., or that they may have more similarity, thus making repairs or additions more adaptable. Wood or other combustible material should never be used unless advisable for temporary work.

(b) **Illumination.**—On account of the emergencies arising in switchboard operation and the necessity for rapid and at the same time sure and safe control, good illumination is necessary at all times, and when natural or ordinary illumination fails, artificial emergency illumination should be instantly available. The delay caused by cautiously reaching for switches on lighting circuits might be disastrous in emergencies, and attempts to handle the switchboard in darkness might expose the operator to unnecessary danger. In some cases, where the entire station is not provided with an instantly effective emergency source of illumination, the switchboard is provided with such means. (See discussion of rule 103.)

172. Necessary Equipment.

Ground detectors giving continuous indication are recommended for all ungrounded outgoing circuits, since chance grounds affect the public safety and convenience directly through danger of shock and indirectly through their possible interference with signal service for fire or police alarms, train operation, or other indispensable service. Some means of detecting grounds is definitely required by rule 145. In the same way ammeters are usually necessary to indicate the existence of overloads, and voltmeters should always be installed on constant-potential circuits to show whether conditions are normal.

173. Arrangement and Identification.

Where bus chambers uniform in design contain busses, switches, or auxiliaries for several circuits, very conspicuous markings are necessary to prevent dangerous mistakes arising from this uniformity. Some companies have even adopted interlocking arrangements by which covers to one compartment can be removed only when the circuit concerned has been elsewhere interrupted or killed.

It is the practice of some companies to install signal lamps under disconnecting switches which automatically glow when the oil switch in the same circuit is open, thus indicating that disconnects may be opened with safety. This is a positive arrangement, as a burned-out lamp indicates closed oil switch.

174. Spacings and Barriers against Short-Circuit.

(a) **Bare parts.**—In some cases bus bars at low voltage are well protected against accidental short circuits by conducting objects through the use of suitable insulating wrappings or by hardwood facing strips secured to the busses.

(b) **Fuses.**—Fuses should not be located between or behind bare live busses. Installation in such positions endangers the operator in removing and replacing them and may endanger persons working on the busses near such fuses.

175. Switchboard Grounding.

(a) **Frames.**—See discussion of rule 113. An outstanding exception to the grounding of switchboard frames is presented in the case of direct-current railway switchboards.

In the opinion of railway engineers there is no question but that the grounding of switchboard frames increases the hazards involved.

(b) **Circuits worked on.**—In stations the neighborhood of the switchboard usually provides the most convenient location for making protective grounds and short-circuits, and the provision, at this point, of a suitable ground connection with adequate means for readily connecting any particular circuit to the ground connection greatly facilitates the uniform provision of this protection for workmen.

176. Guarding Live Parts on Switchboards.

(a) **Guards.**—Fencing between switchboard platforms and passageways leaves the operator free to give full attention to operation and prevents interference with the switchboard by passers-by. The placing of switchboards on galleries accomplishes the same purpose.

Insulating floors have few of the disadvantages in the way of unevenness and unreliability which the less substantial mats and platforms possess, and in the clear, dry surroundings usual with switchboards they afford effective protection to the operator should he accidentally touch one live part of even moderately high voltage. Various materials, such as alberene stone, soapstone, slate, and marble are satisfactory. For insulating mats or platforms a depressed section of floor is often advisable, so that the edges of such mats or platforms can be flush with the floor surface.

The danger of injury from contact with two live parts between which a voltage of more than 750 exists or from contact with one live part and ground where the part is operating at more than 750 volts to ground is so serious that reasonable isolation by elevation or suitable guarding of such parts, even from the switchboard operator, is essential. Even with parts of less than 750 volts the danger from flashes and contact may be considerable, and isolation for unguarded parts in new construction is recommended wherever practicable. An arrangement of switchboards is sometimes provided by which all live parts exposed on the face of a switchboard are at approximately the same potential, and the metal frame is carefully covered with insulating material. In such cases, if the floors are also insulating, the voltage limit may be, with reasonable safety, extended above 750.

The working spaces adjacent to exposed live parts on the face or back of switchboards should be liberal, and where for any reason these spaces are restricted, suitable guardrails or partitions should be provided. Even with liberal working spaces, such guardrails or partitions are to be recommended as likely to protect attendants from injuries by inadvertent movements while near the switchboard.

(b) **Plug-type switchboards.**—Plugs with insulating sleeve guards are available for arc-light and similar plug-type switchboards by which the exposure of live parts at the face of the board may be entirely obviated. Without such protection the plugs of some boards are alive even when the insulating handles are withdrawn several inches from the board, exposing a considerable length of the metal portion of the plug to possible contact of the operator.

(c) **Exposed parts of more than 7,500 volts.**—Very high-voltage parts exceeding 7,500 should ordinarily be guarded against accidental contact of attendants or other persons, but even such parts may occasionally need to be left exposed during operation for examination or adjustment. At these times, which may be quite rare, adequate working space will nevertheless be indispensable for the safety of the attendant. Only in cases where the existence of duplicate equipment or the character of service permits live parts at these high voltages to be made dead before they are approached in an unguarded condition, should it be permissible to dispense with the lateral working spaces called for under the rule.

177. Instrument Cases.

In good practice meters operating on high-voltage circuits are provided with outer metal and glass covers, the metal either grounded or thoroughly insulated from the meter case proper, thus permitting ready reading without danger of injury to the attendant.

Sec. 18. LIGHTNING ARRESTERS

180. Location.

(a) **Where required.**—In the large majority of instances lightning arresters are advisable to protect station equipment supplying overhead line conductors. This is recognized by insurance interests who maintain a differential in premium rates against those stations supplying overhead lines not equipped with lightning arresters.

It is recognized that there will be situations coming under this rule where engineering considerations will indicate the inadvisability of installing lightning arresters. Examples of such cases may be found where some short overhead lines are in protected locations or where overhead lines are operating at very high voltage such as 110,000 volts or more. It is to be expected that the regulatory authority will need to consider individual exceptional cases and grant such waivers from the requirements as appear to be justified.

Lightning arresters are intended to give protection from all kinds of disturbances in electrical transmission systems that take the form of high voltage. There are two sources of high voltage, viz, atmospheric lightning and internal disturbances originating in the line itself. Lightning arresters are designed to take care of atmospheric lightning and those internal surges that are transient in nature, but not those that are continuous.

When a discharge from a cloud strikes an electrical conductor directly it almost always breaks down the insulation at or very near that point. It rarely travels along a transmission line far enough to reach an arrester, and if it did it would probably destroy any type of arrester. Arresters are not designed, therefore, to handle direct lightning strokes. It is usually the line insulators rather than the station apparatus that are injured by these direct strokes, and they are best protected by overhead ground wires well and frequently grounded rather than by arresters.

A surge induced by atmospheric lightning causes damage either because of its high voltage which punctures the insulation to ground, or because of its high frequency which builds up a high voltage across the end turns of the first inductive winding it strikes, thus causing a breakdown between turns. In either case the power current flows through the puncture, and a short circuit or an internal surge is started that may cause great damage.

Internal surges may be caused by any change in load conditions. They may be transient or continuous.

Transient surges are caused by sudden changes of load such as are occasioned by switching, the operation of circuit-breakers, etc. They are usually comparatively unimportant but may be quite severe when a very heavy current is broken suddenly.

Continuous surges are caused by arcing grounds which result in oscillations of great power at a frequency, usually a few thousand cycles per second. These are very destructive. Arcing grounds frequently result from breakdown of insulation caused by lightning. Lightning arresters can not handle continuous discharges such as these for any extended period.

Operating engineers realize that the lightning arrester is a very important piece of electrical apparatus and as such requires to be installed properly and after a proper installation to be inspected often to assure its being in condition to perform its functions in a thoroughly efficient and proper manner.

For the protection of all electrical apparatus it is necessary that an arrester be placed on each ungrounded conductor of every open overhead circuit. Some engineers prefer a single arrester placed on the station bus to separate arresters for each circuit. If one arrester is placed on the bus, the line switch, relays, and transformers are not so fully protected. Should the apparatus be somewhat old its failure is sometimes attributed to the failure of the arrester to function properly, when in reality the fault is more likely to be with the old apparatus than with the arrester.

An important element in the proper protection of circuits against static disturbances is the installation of choke coils and energy-absorbing resistors. Any inductance acts as a partial reflector to high-frequency waves. The energy may be absorbed by using iron wire adjacent to the apparatus to be protected.

Transformers having their end turns provided with additional insulation are protected somewhat from the excessive voltage per turn induced by the high frequency-surge.

(b) **Indoors.**—Lightning arresters have been frequent causes of fires where located near combustible portions of buildings. It is advisable to locate lightning arresters, especially if oil-filled, outdoors wherever practicable. In some types of lightning arresters it is impracticable to ground their exterior metal frame or case, and in such instances these parts should be plainly identified by marking or otherwise and guarded as high-voltage parts for the protection of attendants and others who might presume that these parts were grounded as would be most exterior metal frames and cases of electrical equipment in the vicinity.

181. Provisions for Disconnecting.

(a) **Air-break disconnectors.**—To safely accomplish the necessary cleaning and inspection of arresters on high-voltage circuits, particularly more than 7,500 volts, their disconnection from the live circuit is necessary, and such disconnection is, of course, desirable even for lower voltages.

(b) **Working space.**—The disconnectors installed for this purpose should be provided with adequate working space or else be isolated by elevation. Even when installed outdoors isolation is the best means of protection and though remotely controlled such apparatus should have the same degree of protection as other apparatus of the same voltage.

182. Connecting Wires.

Too much importance can not be attached to the making of proper ground connections. Connections should be as short and straight as possible. A poor contact will render ineffective every effort made with choke coils and lightning arresters to divert the static electricity in to the earth. It is important, therefore, not only to construct a good ground, but in doing so to appreciate thoroughly the necessity of avoiding unfavorable natural conditions. Many lightning-arrester failures are traceable directly to poor ground connections.

183. Grounding Frames and Cases of Lightning Arresters.

Arresters like other types of apparatus connected to the same voltage are susceptible to leakage and therefore should have their frames and cases permanently grounded. It is a well-known fact that oil-type arresters, after several minutes of continuous discharge, carbonize the oil, thus facilitating greater leakage.

184. Guarding Live and Arcing Parts.

(a) **Protection from contact or arcing.**—Though arresters are generally located well away from frequently occupied working spaces, it should be remembered that protection from live parts is as essential to safety here as for other live parts of equal voltage. When placed inside of buildings, clearances should be allowed above horn-gap arresters, as the arc may be considerable at times. The amount of this clearance is dependent upon the proximity of combustible material and also upon the operating voltage of the arrester.

Part 2.—RULES FOR THE INSTALLATION AND MAINTENANCE OF OVERHEAD AND UNDERGROUND ELECTRICAL SUPPLY AND COMMUNICATION LINES

Sec. 20. SCOPE, NATURE, AND APPLICATION OF RULES

200. Scope of Rules.

A. Extent of application.—The rules for lines differ from those for stations and for utilization equipment, where apparatus, equipment, and wires are confined to limited areas where persons are usually present. The safeguarding of persons by actual inclosure of the current-carrying parts, or by use of barriers, or by the elevation of such parts beyond reach is in these latter cases not only desirable but generally feasible. With overhead lines, on the other hand, the wires and equipment are not confined to limited areas and with few exceptions are not under constant observation. Safeguarding by inclosure is feasible with underground lines and, in fact, is in most cases essential to operation. For overhead lines, however, isolation by elevation must be generally depended upon for the safety of persons in the vicinity. This elevation must be much greater than would ordinarily be required inside buildings, because the voltages are more frequently high and because the usual traffic must be properly safeguarded and must be unimpeded.

B. Not complete specifications.—Practice and experience have determined reasonable limits for elevation of lines and equipment and for the strength of construction necessary. The rules do not provide such detailed requirements as are needed for construction specifications but are intended to include the more important requirements from the standpoint of safety to the public and to workmen, grading clearances by the degree of hazard involved, and grading strength requirements necessary to maintain the required clearances both by the degree of hazard and by the mechanical loads which may be imposed according to the recorded wind and ice conditions in the district concerned.

C. Conformity with good practice.—The required construction is intended to be in accord with good practice and, indeed, to set a standard of good practice in many respects. Safety is promoted by uniformity in practice, which tends to avoid confusion and misunderstanding both in construction and operation. Workmen migrate frequently from place to place, and if practice varies widely mistakes are multiplied and accidents are more frequent.

201. Application of the Rules and Exemptions.

A. Intent, modification.—The rules are intended to be observed completely in new work under usual conditions. Sometimes alternatives or exemptions are provided in order that the rules may take care of special cases without hardship or unreasonable expense. It is, however, impossible to foresee all conditions that may arise, and it is expected that the rules will be modified or suspended by the proper authority when necessary to meet special or unusual conditions.

B. Realization of intent.—The replacement of existing construction to secure compliance of the entire installation with the rules would in most cases involve unwarranted expense, and hence such replacement is not contemplated. When, however, an extension or reconstruction is being carried out which is of relatively large proportion, it may be advisable to reconstruct certain other portions of the installation to comply with the rules and suitably safeguard the installation. In some cases it will be feasible and proper to reconstruct, as far as necessary, the entire installation to comply with the rules.

Existing installations can in some instances be made less hazardous by the proper placing of guards and signs. This method of safeguarding is usually attended with small expense and is generally effective.

In considering the application of the rules to existing installations it is evident that some rules can be made effective at once without unwarranted expense, and so assist in safeguarding the workmen and public, and frequently with distinct benefit to service no less than to safety. Such improvements should be made as rapidly as possible after the rules become effective, and a program should be arranged for future replacements and improvements on some reasonable schedule having the approval of the administrative authority. Such reconstruction can, of course, usually be done most economically at a time when important extensions or reconstructions are being undertaken for other reasons than accident prevention, as noted above.

On the other hand, it may sometimes be impracticable when extensions or reconstructions are undertaken to comply fully with the rules. The arrangement of the cross-arms on a single new pole so as to have the supply wires above communication wires, when the other poles of the line still continue with the arms in the reverse relation, would add to the danger instead of reducing it. Other instances where compliance would be impracticable will be recognized by the administrative authority as they occur. Alternatives which would not be considered adequate for new installations may often be permitted in old ones.

C. Waiver for temporary installations.—Good judgment must be exercised in the case of temporary installations as to how far the rules should be complied with. Safety to employees and others should not be overlooked, and yet construction in some cases may be very different from that required for permanent installations, as the expense of complete compliance would often be prohibitive. Temporary installations will probably not encounter the worst weather conditions.

D. Waiver in emergencies.—In many cases it will be necessary for the person in responsible charge to decide what rules should be waived, as decisions must often be made quickly. Such decision is, of course, subject to review by the proper authority, and the person making it must assume responsibility for the consequences.

Where the construction involves other utilities, as at crossings and with joint use of poles, it is intended that the appropriate officials or other representatives of such utilities should be notified before action is taken.

202. Minimum Requirements.

The rules are intended to be reasonable in every respect, and in many particulars do not require as substantial or expensive construction, as many companies have found it practicable and desirable to provide for other reasons. Hence, the requirements may appear in some cases too lenient. If the rules are complied with generally, however, it is believed that a distinct advance will be made over much existing construction and practice. It is considered that a good balance between the different factors concerned in the safety of line construction is preferable to an excess in some, which might, perhaps, entail a deficiency in others, as there are limits to permissible expense. It is believed better to have reasonable and moderate requirements with which it is practicable to comply very generally than ideal requirements that are so severe as to be unenforceable in many instances. As experience justifies it, the requirements are expected to be modified in subsequent editions of the code.

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Sec. 21. GENERAL REQUIREMENTS APPLYING TO OVERHEAD AND UNDERGROUND LINES

210. Design and Construction.

This rule, paralleled also in the parts dealing with stations and utilization equipment, strikes the keynote of the code. There is no intention of requiring or even recommending more expensive construction than good practice requires and good business justifies. But it must be remembered that the public in the end pays whatever extra cost is caused by requiring safer and better construction, and, hence, the public may rightly require a good degree of safety in the construction. However, since the circumstances vary so widely, it is necessary that the rules provide for considerable latitude in construction of lines according to the varying degree of hazard, the number of persons exposed to the hazard, and other determining conditions. In cities and congested areas, where the population is relatively dense and the exposure to hazard from unsubstantial construction is correspondingly great, the greater business will, of course, pay for safer and more substantial construction than can be afforded or is needed in sparsely settled communities. The code has taken these differences carefully into account, and the requirements are much less for rural than for urban districts.

211. Installation and Maintenance.

This is a general statement of the object and purpose of the code, and the bulk of the rules are concerned with applying this principle in detail to the various items of construction as they come up in different situations. It is recognized that hazards can not be entirely eliminated in all cases, and the big problem in formulating rules is to decide how far it is practicable to go in reducing hazards.

It is not sufficient to care for possible hazards in original construction. Deterioration takes place in materials of construction, especially wood. Inspection and maintenance work are essential to keep check on conditions and to preserve adequate safety. Certain of the rules specify quantitatively the amount of deterioration permissible before replacement, but, in general, this must depend upon the good judgment of those in charge. This subject is further considered in rule 213.

212. Accessibility.

Although necessary to isolate line conductors and equipment thoroughly for protection of the public, it is essential that they should be safely accessible to authorized persons in order to facilitate the necessary adjustment or repairs and so maintain service as reliable and safe as practicable. (See also rule 285, B.) Other rules of the code, particularly those of section 23, specify in detail the proper clearances and separations for conductors and the proper location of the wires and apparatus in order to provide this safe accessibility for authorized employees.

213. Inspection and Tests of Lines and Equipment.

A. When in service.—It is not intended that new construction shall be inspected by State or city officials before being put into use, or that such official inspections shall be regularly made. Occasionally they may be made as a check upon the inspection of the owner, but for the most part the operating company must make its own inspections. These should be so managed as to secure adequate and reliable results, the inspectors preferably being independent of the construction or operating force.

B. When out of service.—Lines out of service, like idle machinery, may require careful inspection and repair before being fit for active duty and should not be permitted to become a hazard through neglect.

214. Isolation and Guarding.

A. Current-carrying parts.—The provision of adequate clearance from conductors and other current-carrying parts to the ground or other space readily accessible to persons is essential if such parts are not effectively guarded so as to prevent persons from coming into accidental contact with them. The lack of sufficient clearance from bridge abutments, over roofs, and from windows of buildings is the cause of a considerable number of deaths annually. Very liberal clearance at such points, or, when that is impracticable, fencing or guarding the conductors to prevent accidental contact with them, is essential. (See sec. 23.)

B. Noncurrent-carrying parts.—The discussion for rule 215, B also shows the importance of this rule.

215. Grounding of Circuits and Equipment.

A. Methods.—The subject of grounding has been thoroughly studied in connection with the preparation of the rules of section 9. Extensive inquiry has been made throughout the country as to practice and opinion, and it is believed that the rules prescribed can be depended upon as expressing the best experience of the country on this subject.

B. Parts to be grounded.—The purpose of this rule is to protect persons coming into contact with metal conduit, cable sheaths, metal frames, cases, etc., from receiving a dangerous or fatal shock, as has often happened when such metallic bodies were ungrounded and in contact with high-voltage supply circuits. This is one of the most important safeguards in handling high-voltage equipment. If out of reach from the ground, or if approached only by qualified workmen, grounding is not required. The hazard to a workman who must handle live parts is increased by the presence of grounded surfaces within easy reach.

For this reason grounding is not made mandatory when low-voltage circuits only are involved, as the hazard from such circuits is relatively small.

C. Use of ground as part of circuit.—The use of the ground for the return portion of telegraph circuits and other communication and signaling circuits has long been customary and is for many purposes satisfactory, although for telephone purposes it is recognized that such practice makes service more subject to interference than where a metallic circuit is utilized. For supply purposes a similar arrangement has been sometimes used, but it has objections from both the service and the accident standpoints, and its use is considered undesirable. Where artificial grounds are depended upon for the ground connection, the chances of trouble from high-resistance grounds loom large, and although the prohibition introduced into this edition of the code is mandatory only in urban districts, the practice should be discouraged everywhere.

216. Arrangement of Switches.

In addition to the customary uses of switches for disconnecting and connecting lines and apparatus, it may be considered advisable to install them in all supply services, either overhead or underground, operating at voltages in excess of 750 volts, on the structures from which such services enter buildings or premises. The operation of switches installed under these conditions may be of considerable value during a fire in preventing contact with live lines or equipment.

B. Indicating open or closed position.—Inaccessible switches and switches that do not show at a glance whether they are open or closed tend to increase mistakes in operation and to multiply accidents. This is especially the case in emergencies when quick action is necessary and time can not be taken for consideration of unusual connections or arrangement of switches. In this connection it is often advisable to identify oil and air switches by numbering or lettering them, especially where a large network is concerned. Workmen often become confused where directions only are specified, so that serious accidents may occur where the wrong switch is opened or closed, as the case might be.

C. Uniform position.—Uniformity of position and of method of operation makes it easier to avoid mistakes and so promotes rapid and safe operation. A system in which this rule is observed not only is safer, but also makes a much better appearance and is more creditable to the designer. If practicable, means should be provided to lock or otherwise secure each switch in either the open or closed position. Some types of switches may require considerable change in design in order to permit this to be done.

Locking is especially important where men are working on a line which is made dead by a switch, the control mechanism of which is readily accessible to unauthorized persons.

A case was recently reported where a lineman was killed on account of the closing of such a switch at night by unauthorized persons.

Secs. 22 to 28. RULES FOR OVERHEAD LINES

Sec. 22. RELATIONS BETWEEN VARIOUS CLASSES OF LINES

220. Relative Levels.

A. Standardization of levels.—The great convenience and simplicity of having each class of conductor at a definite level is at once apparent when we consider crossings and joint use of poles. Such situations can then be approached without any change of the levels used at other points and complicated construction is thus avoided.

B. Relative levels—supply and communication conductors.

1. *Preferred levels.* —It is universally conceded that the proper relative position, in general, for supply and communi-

cation conductors is to have the former above and the latter below. The reasons for this are stated in the note. There was formerly a widespread disposition to run fire-alarm wires at the highest position on a pole with the idea that failure of other wires would not affect such circuits. This policy has now been largely abandoned and fire-alarm conductors are usually placed below supply conductors.

In connection with this subject consideration should be given communication circuits which are operated purely as dispatching circuits of supply utilities. These circuits generally parallel high-voltage supply circuits for long distances, and consequently high voltages may be induced on the conductors, which make them fully as hazardous as some supply conductors. For this reason exception should be made for such wires in the statement that communication circuits should be placed below supply wires. Where the supply circuits customarily employed for distribution purposes are installed on the same poles with dispatchers' circuits and high-voltage supply circuits, they should be installed beneath the communication wires. The construction of the latter will be determined in accordance with rule 288.

2. *Minor extensions.*—It would involve undue expense to specify the immediate standardization of all present construction in conformity with these rules. This would work a very severe hardship on utilities in localities where it has been the practice to place the signal wires above the supply wires. A gradual change to the best type of construction is recommended, and small extensions of the present arrangement may be made provided the construction conforms to the grade required.

3. *Special construction for supply circuits, etc.*—For many years it has been the practice of certain railroads to run circuits which supply power for operating signals upon the

lowest cross arm of the telegraph line. In view of this established practice, which is not known to have resulted in any definite hazards, a special rule has been written recognizing and permitting the continuance of such an arrangement, but only after cooperative consideration with the owners of other circuits which may be involved on the same line. Definite restrictions and limitations are applied to this practice.

Circuits used for signaling purposes or train control which meet the definition of communication circuits are not restricted as to common occupancy of poles or cross arms with other communication circuits.

C. Relative levels—supply lines of different voltage classifications.

2. *On poles used only by supply conductors.*—(*a*) There are several considerations which make it desirable to have the circuits of higher voltage on a pole at the higher level, and where there are circuits of a number of different voltages on a pole to arrange them according to the voltage, with those of highest voltage on top and preferably a space of more than the gain spacing between groups of different voltages to serve as a dividing line. From the standpoint of linemen and trouble men it is desirable, because the lowest voltage circuit will usually be worked on more frequently and the higher voltage circuits less frequently. The arrangement here proposed makes the lower voltage circuits accessible without coming into proximity with the high-voltage wires and necessitates less climbing. Circuits of the higher voltage classifications should provide greater service reliability than circuits of lower voltages; they should be maintained in more secure condition mechanically and, hence, require less attention.

It is much safer to climb through wires operating at low voltages. Wires operating at extremely high voltages are generally killed before being worked on. There would, however, be objection to killing them if it is desired merely to climb through them to work on the low-voltage wires which were placed at a higher elevation.

The advantage of having the higher-voltage circuits above the lower-voltage circuits is particularly evident, when the types of apparatus which operate on supply lines are considered. The installing and removing of transformers is, at best, a rather hazardous undertaking when the supply wires are alive, and considerably more so when the transformer must be handled through high-voltage supply wires. The arrangement of the transformer secondaries so as to provide clearances also offers some difficulties where a higher-voltage circuit is below the transformer.

Where it is not practicable to carry the higher-voltage wires at the higher levels, the construction of such lower-voltage circuits as are placed above those of a higher classification must, in general, be made as strong as is required for the higher-voltage circuit in the preferred arrangement.

221. Avoidance of Conflict.

Parallel lines offer three possibilities—overbuilding, conflict, and complete separation. Overbuilding involves all of the hazards of joint use of poles, without any of its benefits. Proper clearances are difficult to maintain unless clearance arms are used, on account of angles in the line and of the impossibility of keeping the poles of each line exactly vertical. To avoid overbuilding it is usually necessary to occupy opposite sides of the road or street. When more than two utilities occupy the same highway, a conflict is almost inevitable unless resort is had to joint use of poles. The preferable condition is complete separation of the two lines, except as conditioned in rule 222.

A distinction has been made in this edition of the code between a structure conflict and conductor conflict. These terms are separately defined in section 1. A structure conflict occurs when the overturning of a pole will result in contact with the conductors of a second line. A conductor is in conflict when it is located at a higher level than the conductor of another line and within a horizontal distance from it as specified in the definition, and so selected as to represent a case where there is likelihood of contact if the first conductor becomes broken. It is evident that some conductors of a line may be in conflict while other conductors of the same line are not in conflict, and in such cases the grade of construction incidental to such conflict applies only to the former. A structure conflict may or may not be accompanied by conductor conflict, but in most cases it will be. It is desirable to avoid both types of conflict and such avoidance as referred to in this rule applies to both forms.

222. Joint Use of Poles by Supply and Communication Circuits.

The ideal condition from a safety standpoint when considering two overhead lines, one a telephone or telegraph line and the other a supply line, which for any reason must follow approximately the same route, is that in which the two lines are adequately separated. This is generally recognized. In the case of main toll communication lines and high-voltage transmission lines, the ideal of adequate separation can generally be realized. Occasions may arise when communication and supply lines can not be so separated. On account of the increased loads on supply lines and the necessity for extending the ordinary distribution circuits long distances into rural districts, the tendency is toward the use of higher voltages for distribution than have been usual in the past. It is customary for such lines to follow the roads.

Where it is impracticable to secure entire separation of the communication and high-voltage lines, a choice must be made between a joint line and separate pole lines, one of which conflicts with the other. Both of these types of construction are covered by the rules. Section 24 specifies the strength requirements for lines which must be in conflict, the grade of construction depending on the voltage of the supply line concerned.

There are cases where one method is to be preferred to the other. Conflicting lines which are not overbuilt naturally offer less opportunity for accidental contact between the conductors of the supply and communication lines, since the likelihood of a broken supply wire falling on a communication conductor is greatly reduced. The possibility of broken poles bringing the two classes of conductors into contact is also perhaps more remote with this method of construction. Such a conflicting line always offers a less degree of hazard than a colinear line and is for the above reasons preferable to joint use of poles when considering supply lines which operate at a voltage against which the communication protective apparatus does not offer sufficiently reliable protection. On the other hand, a joint line is always to be preferred, from the safety standpoint, to overbuilding.

The joint use of poles may be very desirable to the utilities concerned for several reasons and under some circumstances is safer. The cost of construction and maintenance to each is naturally less when shared by two or more utilities, even considering the additional strength of construction required. One great benefit to be derived from the joint use of poles is the reduction in the number of supporting structures on the streets within municipalities. These are usually considered unsightly, and, if very numerous, detrimental to a city's appearance.

Inasmuch as the available routes for the distribution networks of telephone and supply services must frequently coincide, and as the users of both services are, to a large extent, common, the lines of both classes of service will, in general, occupy the same streets or alleys. As the voltage of the supply lines constructed under this condition is, in general, within the limits against which the telephone utilities have been able to install satisfactory protective apparatus, a joint line of poles is the only logical solution of the questions involving the details of construction. Even when higher voltages are carried on the same poles, a joint line is regarded as safer than separate nonconflicting lines which must have service drops to customers' premises crossing under or over each other. The presence of many such services should determine a decision in favor of joint use, especially when the alternative is either a conflicting line or separate lines on opposite sides of a street, which under the definition are not in conflict, but yet involve the possibility of mechanical interference.

Where the joint use of poles is made by different utilities there is generally a mutual and reciprocal agreement between them providing for such joint use, and thus a higher degree of cooperation is obtained than is ordinarily found where the utilities are on separate poles. This spirit of cooperation is very valuable and assists greatly in maintaining a high standard of construction.

In the case of electric railway lines it is often necessary or desirable to have them on joint poles with communication circuits, but such joint use frequently involves only the attachment of a trolley span wire to poles of the communication line. Where trolley contact wires are supported by span wires attached to a double line of poles, it is generally desirable to put the trolley feeders on one line of poles and the communication wires on the other line of poles.

Sec. 23. CLEARANCES

230. General.

B. Constant-current circuits.—Where a person may come into contact with a constant-current circuit, the hazard depends mainly on the voltage of the circuit. The additional hazard occasioned by the value of the current is discussed elsewhere.

C. Metal-sheathed supply cables.—Where cabled conductors are covered merely with insulating material, they are treated the same with respect to clearances as are single conductors with similar covering. When cables are covered with a grounded metal sheath or armor, the conditions are entirely different, since such metal can not carry a high voltage but is at ground potential. It can, therefore, be treated with respect to clearances as a low-voltage conductor. A similar distinction is made in rule 241 with respect to the grade of construction required.

D. Maintenance of clearances.—Repeated wind and ice storms will stretch soft copper beyond its yield point, and thus permanently increase the sag. When the sags have increased sufficiently to reduce the clearances specified in this section they should be readjusted to comply with the rules. The necessity for frequent adjustments should not exist, as it endangers linemen and indicates a condition dangerous to the public. For this reason the use of soft copper, especially in the smaller sizes, is not recommended, and better conditions will be secured by the use of medium hard-drawn wire. This is more fully discussed in connection with rule 261, F 1.

While wires of other materials do not entail such frequent attention, it is necessary to check them occasionally also to see that clearances are maintained.

231. Horizontal Clearances of Supporting Structures from Other Objects.

A. From fire hydrants.—A minimum clearance must be provided between line structures and hydrants, not only to make the latter accessible when needed but also to prevent excessive wear and tear to the pole or guy which it would receive if too close to the hydrant. In many cases it might be desirable to make this clearance considerably more than 4 feet. When not practicable to allow 4 feet, a reduction to not less than 3 feet may be permitted.

B. From street corners.—Where hydrants are located at street corners, junction poles located near them are at a disadvantage in that they can not always be placed at the intersection of the lines, and this may make necessary the use of inconvenient flying taps. An effort should always be made to avoid this type of construction, as such taps are inaccessible from the pole. Where the curb corners at street intersections are rounded in character and the block corners are occupied by tall buildings, it is often extremely difficult to make the construction of the overhead supply lines of the very best grade. It is necessary to install at least one and sometimes more additional supporting structures to provide proper clearance between the wires and the buildings.

C. From curbs.—Setting poles and guys back from the curb at least 6 inches is, in general, a satisfactory means of avoiding considerable wear from wagon hubs.

D. From railroad tracks.—Specified side clearance between railroad tracks and poles is desirable for several reasons. If poles are too close to tracks rails, men swinging out from the sides of moving cars would be in danger of striking such poles and being injured. Other conditions, however, call for still greater clearances. It is customary to run a ditch parallel to the rails in order to secure suitable drainage for the roadbed. Such ditches may be as far as 10 feet from the rail and it is desirable to have the intervening space clear so that ditching machines, for example, may be operated on the tracks. A suitable clearance here also makes it easier for the locomotive driver to secure an uninterrupted view of signals and of conditions along the right of way. It is also desirable that there be sufficient space for a vehicle to pass between a line of poles and the tracks without serious hazard; 12 feet is considered adequate for the above purposes where rapidly-moving trains are concerned. At sidings, where cars are usually stationary while vehicles are passing, considerable less space will prove sufficient.

Where trolley poles are placed between car tracks, this clearance is, of course, unnecessary, but a new hazard—that of passengers putting arms or heads out of windows or over platform gates—must be guarded against either by screens or adequate clearance.

232. Vertical Clearance of Wires Above Ground or Rails.

A. Basic clearances.—The clearances of line conductors above railroads, roadways, and footways have been specified at widely different amounts by different States in their statutes and commission orders. Local variations in practice exist even where no rules are in effect. In general, no such variation in traffic exists as will justify these varying requirements, and the establishing of much higher clearances in one community than in others tends to encourage the local use of high vehicles, such as hay derricks, well-drilling outfits, furniture vans, etc., which, when carried into the neighboring lower-clearance communities, may cause serious hazard.

In consideration, therefore, of accidents due to insufficient clearance or to the building of high loads on vehicles, and in consideration of general practice and the advantage of a more nearly uniform practice, the clearances of Table 3 have been established.

Railway freight cars will usually not much exceed a height of 15 feet. In most communities cars of greater height are already eliminated by low highway bridges, which are often much lower than the wire clearances specified, partly because they are not subject to sagging and partly because their number is limited and their locations can be readily learned by brakemen.

The clearances of 27, 28, and 30 feet are required for conductors in crossings over railways, the clearance depending on the voltage of the line. It has been recommended that 30 feet be specified as a minimum clearance in all cases. In certain sections of the country 27 feet has been used for years as a minimum clearance for the lower-voltage lines, therefore it does not seem justifiable to make a 30-foot clearance a national requirement. The minimum values given do not necessarily imply that in localities where 30 feet has been used as a minimum clearance this value shall be reduced to the code values.

The clearances of 18, 20, and 22 feet as required for supply conductors crossing over railways not included above are intended to be used, in general, in connection with electric and steam roads operating only passenger trains where men are not permitted on the tops of cars while the cars are in motion.

For wire clearances above highways, the traffic under consideration, of course, varies more in its clear-height requirements, although the ordinary roadway vehicles are much lower than freight cars. The higher vehicles which are to be considered are hay wagons, box loads, moving vans, etc. Elevations of such vehicles above ground exceeding 12 to 14 feet will be very rare, and it is quite practicable to restrict ordinary traffic to vehicles not exceeding such a height. Those responsible for the traffic of vehicles more than 12 or 14 feet high can reasonably be expected to know that obstructions exist along highways to prevent riding on the tops of such vehicles (such constructions including overhead bridges, branches of trees, trolley and other wires), and to know also that contact with overhead wires is frequently dangerous to themselves or to the wires and should always be avoided. A minimum wire height of 16 to 22 feet, according to the character of the road, seems, therefore, fully warranted.

The moving along highways of such devices as hay stackers, well rigs, and derricks must always be considered as extraordinary traffic and subject to the necessity of observing special precaution against contacts with overhead obstructions of all kinds. Such vehicles otherwise may endanger the community by injuring overhead structures. Frequently it is quite practicable to reduce the elevation of such vehicles, but this is often neglected, and the low-wire elevation is sometimes accused of responsibility for entirely avoidable accidents arising out of culpable negligence of the drivers of the vehicles.

Note *c* of Table 1, rule 232, permits a clearance of 25 feet between wires of less than 15,000 volts and tracks where men are permitted to ride on tops of freight cars, if the wires are paralleled by trolley contact conductors. A reasonable distance between the two parallel sets of wires crossing the tracks, and also a clearance of about 22 feet between the trolley wire and tracks, are presupposed. The reduction in clearance from 27 or 28 feet to 25 feet is justified on the ground that anyone on top of a car who could possibly touch the higher wire would be bound also to touch the lower trolley wire. The 3 feet extra clearance is asked to take care of any increase in sag due to ice load (which will not usually accumulate on trolley wires) or other causes.

Supply service leads when of less than 150 volts to ground may have a clearance of only 10 feet at the entrance of the service to the building. This exemption is made, as it is

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often impracticable to give a greater clearance, and the voltage of the circuit does not offer any considerable hazard.

It is hoped that the given clearances will tend to secure desirable uniformity in practice throughout the country, but there may still be some communities where the importance of traffic with vehicles of extraordinary height will warrant an increase of the minimum requirements given. On the other hand, there are some communities where vehicles are so closely limited by low railway-bridge clearances that less wire clearances may be justified. The former modification, of course, entails no disadvantages where vehicles go to other communities, whereas the latter involves this danger.

B. Increased clearances.—It is recommended, in general, that the spans at railway crossings be kept as short as possible and preferably under 200 feet. However, where spans exceed 150 feet, the clearance at crossings shall be increased.

The greater clearances are necessary because of the greater sags in the longer spans due to ice loading or extreme temperature rise. More accurately still, the rule should differentiate between small and large conductors and different materials, since the variation of sag is greater with small than with large conductors unless the smaller wires are given large initial sags. But as the smaller conductors are limited, partly for this reason, to the shorter spans (see rule 261, F), the complexity which a variation of clearance with conductor size would cause seems unwarranted by the slightly greater accuracy.

As the length of span, and consequently the normal sag, is increased for a given conductor, the change in sag due to ice loading or to high temperature at first increases also, but eventually reaches a maximum and may actually decrease again for very long spans. This maximum value depends upon the size of wire and other conditions, but a limiting value for the increment in clearance has been chosen which will take care of all increased sags under the conditions imposed.

It is fairly obvious that high-voltage conductors need greater clearances than low-voltage conductors. Not only is contact with them more hazardous, but the higher voltages may actually flash across an intervening air space to a person or object not coming into actual contact with it. The table gives definite increments of clearance for larger voltages up to 50,000 volts in steps. Above that value there is a steady increment for any increase of voltage above 50,000 volts.

A few inches displacement of the free end of a suspension insulator toward a crossing span it supports might reduce the clearance of such a span by as many feet. While not necessarily a dangerous reduction, where the clearances are relatively large, as over railroads, a reduction in clearance of several feet from conductors only a few feet below would, perhaps, be dangerous. Of course, a few inches movement of a suspension insulator toward a crossing is entirely probable in sleet or even windstorms. If, however, there are suspension insulators at both supports, only the differential displacement is involved, and this will be slight. The rule ignores the resulting change in sag, although it is possible that in some cases the change will be material. The greatest effect is produced by a broken conductor at a near-by point. The rules are so worded as to modify the clearances to provide for these conditions.

233. Wire Crossing Clearances.

A. Basic clearances.—The required clearances of conductors are based on a 100-foot length of span because conductors of some sizes ordinarily used, if in longer spans, have considerable movement, blowing up when there are severe winds and sagging down in hot weather or from ice loading, thus making it possible for conductors of long spans to reduce dangerously the small clearances named as adequate for short spans. The clearances given necessarily assume that both the blowing up of the lower conductor and the sagging down of the upper shall never dangerously reduce the clearances.

Where these clearances are as low as 2 feet, this is probably a safe space for spans of moderate length with conductor sags as great as 3 feet at 60° F., since the blowing up of the lower conductor will seldom equal 1 foot, or the sag of the upper conductor increase by pole deflection, temperature, or ice loading as much as 1 foot. With the smallest conductor sizes permissible, however, the sags increase rapidly with span length, and both the blowing up and the range of the sag beyond that of 60° F. are so increased with even moderate span lengths that the minimum clearances given in Table 3 need to be rapidly increased for the longer spans. (See rule 261, F, and discussion.)

The matter of providing adequate clearances for conductors over guys, span wires, and messenger wires is of as much importance as where two systems of conductors are involved. Line conductors at high voltages occasionally have been given so little clearance normally from guys, span wires, and messengers that with summer temperatures or ice loading elongating a conductor carried above a guy wire, or with slight slacking of a guy carried above the conductor, or with settling of a pole, they have come into contact. Also, in the case of messenger wires supporting communication cables it is necessary that safe separation be provided from supply conductors, so that workmen out on the cable messenger are assured a free access to all parts of the span. Where the relative levels are reversed, so that telephone cables are above supply wires, the clearances must be greater than those specified in the table or telephone linemen can not safely work out on the cable. The smaller size of communication conductors and the small initial sags permitted for grade C communication conductors by rule 261, H, makes the increase of sag under ice load excessive as compared with that of supply conductors, and requires, in general, larger clearances when communication lines cross above supply lines than where the opposite or recommended relation of levels is used.

The clearance of 2 feet specified should be the minimum clearance provided where fire-alarm wires or private communication wires are involved. In cases where communication circuits for public use cross, conflict, or are on joint poles with each other the clearance of 2 feet may be reduced where desired, as permitted in note *b* of Table 3, rule 233.

B. Increased clearances.—See discussion of rule 232, B.

234. Clearances of Conductors of One Line from Other Conductors and Structures.

A. Clearances from conductors of another line.—The 4-foot minimum in this rule will usually be controlling, but in case of long spans (large sags) and high voltages a limit may be set which is larger than this.

B. Clearances from supporting structures of another line.—If conductors of one line are not kept well away from poles of a second line, they are liable to move into dangerous proximity as both pole lines settle or are pulled out of line by service drops. This is especially likely to be dangerous when the conductors of one line straddle the poles of the second line. The rule will practically prohibit the latter construction unless the poles of the two lines are not far apart and span lengths about equal.

It is generally preferable to attach the conductors of one line to the poles of the other by means of clearance arms, and thus eliminate the possibility of accidental contact between the conductors and poles or of the reduction in the climbing space of one line or the other. Otherwise the greater clearances of this rule are necessary. Linemen do not always pay proper attention to foreign wires not on the poles being worked on, so that such wires should, if possible, be given additional clearance.

C. Clearances from buildings.—The efficiency of firemen is much reduced when they are hampered by the proximity of

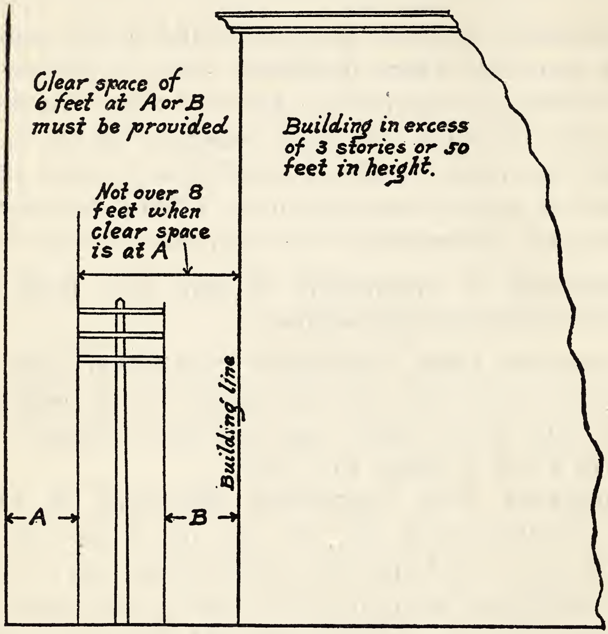

FIG. 5.—*Clearances of conductors from buildings to provide fire-ladder space*

electrical conductors. This is due to mechanical interference with ladder raising and hose handling, as well as to the fear of serious electrical shocks. The clearances indicated will be sufficient usually to permit effective work of firemen. (See figs. 5 and 6.)

The possibility of receiving a shock from a high-voltage wire through a hose stream is one regarding which frequent inquiry is made. For short distances between nozzle and wire such shocks are quite possible. At some distance from the nozzle it will be observed that the stream of water breaks up into discrete particles which do not form a continuous conducting path, and tests have shown that when this distance is reached no shock can be received through the hose stream. Line wires consequently will seldom offer any hazard to a fireman handling hose on the street. Experi-

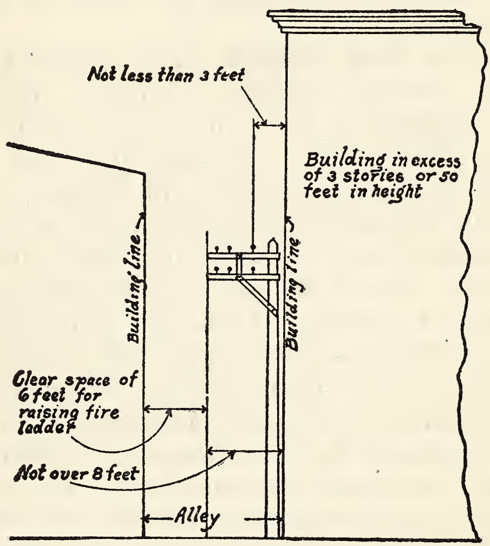

FIG. 6.—*Clearances of conductors from buildings to provide fire-ladder space*

ments are described by F. C. Caldwell, The Sibley Journal of Engineering XXVII, page 321; May, 1913.

Experiments have been made by the Central Hudson Gas & Electric Co. using a solution and nozzle of a type used in spraying fruit trees. Such a spray was directed upon a 66,000-volt line with suitable instruments installed to detect any leakage of current to the nozzle. It was concluded that there is no danger to a man holding the nozzle of such a spray machine provided that the nozzle is 5 feet or more from the line wires and that the flow from the nozzle is not in a solid stream.

Frequently it is the practice to maintain secondary conductors on racks or brackets along the rear walls of houses. The conductors should be made reasonably inaccessible for any voltage of more than 300 to ground, as by placing them near the eaves out of usual reach, or else they should be positively guarded. Inclosure by conduit is desirable under these conditions.

D. Clearances from bridges.—The clearances given are designed to prevent contact of supply conductors with bridges by swinging in the wind or by sagging with ice or high temperature. They are also intended to provide adequate clearances for painters and others who may have to work about ordinarily inaccessible parts of bridges. The clearance required from accessible portions of bridges (3 feet for voltages less than 7,500) is very moderate and is usually exceeded in good practice. Three feet is probably sufficient for horizontal distance from wing walls readily accessible only to workmen, but insufficient in many cases for even horizontal distance from spaces accessible to children, and is always insufficient for elevation above spaces accessible to the public, for which see rule 232. The necessity for warning signs is apparent, since persons will often trespass on parts of bridges and other structures where they are not permitted to go. It is customary to attach a conductor directly to the supports of bridges, and as these are generally fairly close together and the sags are consequently quite small, less separations than are required in other locations may be used. (See rule 235, C.)

235. Minimum Line-Conductor Clearances and Separations at Supports.

A. Separation between conductors on pole lines.—The values specified in Table 6 for the separations of conductors are minimum values only and apply where the spans are short and the sags small. Where the sags are great it is, of course, necessary to increase the separations to provide sufficient clearances in the span when the conductors swing in opposition to each other. This is provided for in Tables 7 and 8. Where the conductors operate at voltages in excess of 7,500 volts, the separation is increased by an increment which is determined by the sparking distance. This distance, however, is not directly proportional to the voltage, but the increment has been made so in order to simplify computations and provide a working value.

The conductor separations called for according to the sags probably provide sufficient space for workmen on poles and also to prevent swinging together, except for the smallest permissible conductors, which swing about more in the wind because of their relatively large sags. It is partly for this reason that span lengths of small-sized conductors are necessarily restricted in rule 261, F. It is a matter of experience, however, that No. 8 and No. 6 hard or medium copper conductors, with sags at 60° F. of 40 inches varying to 55 or 62 inches under load (see Appendix A), are likely to blow together occasionally because of their large sag and their small weight. Fortunately, such conductors are usually covered with insulation which assists in preventing short-circuits and burn-offs, thus reducing the number of falling wires. It is, however, bad practice to string these sizes in spans as long as 150 feet without increasing the separation beyond 12 inches, as is required by these rules, and the danger would be increased were the insulating covering omitted. No. 6 soft copper, with 48-inch initial sag and a much larger sag variation under load than medium copper, will, of course, usually require a larger separation than the medium copper under like conditions.

It has seemed wise to adhere to a comparatively simple rule for separations and to make separations depend on voltage, wire size, and sag.

The apparent sag of a span can be assumed to be the same as the normal sag for supports of equal height in the computation of clearances and separations, up to and including a span in which the difference in elevation of the supports is not more than one-third of the span length, in which case the error will not be greater than 5 per cent. For situations where the difference in elevation of the supports is greater than that stated above, the apparent sag should be used. In terms of the normal sag, the apparent sag is equal to the normal sag of a span having the same length as the one in question, with supports of equal height and same maximum tension of wire, divided by the cosine of the angle formed with the horizontal by the line joining the points of support of the wire.

When suspension insulators are used and are not restrained from motion, such conditions as changes in temperature and ice loading would cause the free end of the insulator to move in the direction of the line. A movement of only a few inches of the free end of the insulator would, in some instances, increase the sag of the conductor by as many feet.

The minimum clearance of conductors attached to suspension insulators are those clearances at the extreme position to which the insulator is displaced. It is very possible for a 60-mile wind blowing at right angles to the line under some conditions of loading to swing the insulator 45° from the vertical position. The values of Table 5 being minimum clearances should be complied with even when suspension insulators are used and are displaced 45°.

4. Conductor separation—vertical racks.—In some localities it is customary to install the low-voltage secondary conductors on racks attached directly to the poles. Such construction facilitates the connection of services and of branches and simplifies the wiring on the poles. However, the climbing space can not be maintained continuously on one side of the pole. It is therefore necessary to supply sufficient lateral working space both above and below the racks to permit the workmen to worm around them.

Where conductors are supported by racks, it is considered that a separation of 4 inches is a satisfactory value, provided the voltage is less than 750. However, it is assumed that due care is exercised when the conductors are installed in order to have the same separation in the spans. Formerly this rule required that the smaller conductor be placed beneath the larger ones. However, the neutral conductor has been installed above the other conductors of a three-wire system by some utilities for purposes of protection, especially where high-voltage conductors are on a higher cross arm. As the neutral conductor is generally the smaller in size, the rule has been reworded to permit this type of construction. Rule 235, C, permits a less separation between conductors which are supported at frequent intervals, as the small sags possible under such conditions and the general lack of disturbances will prevent the conductors from swinging together.

5. *Separation between supply lines of different voltage classifications on the same cross arm.*—In many cases, because of lack of vertical space on the poles or the necessity for stringing additional conductors, it is impossible to install more arms in order to provide proper separation vertically between the conductors of different classification. In order to provide safe construction under these conditions the requirements of this rule will permit two circuits or sets of conductors to occupy the same cross arm in the four cases listed, providing a sufficient separation is maintained. (See fig. 7.) The first two cases may be applied to com-

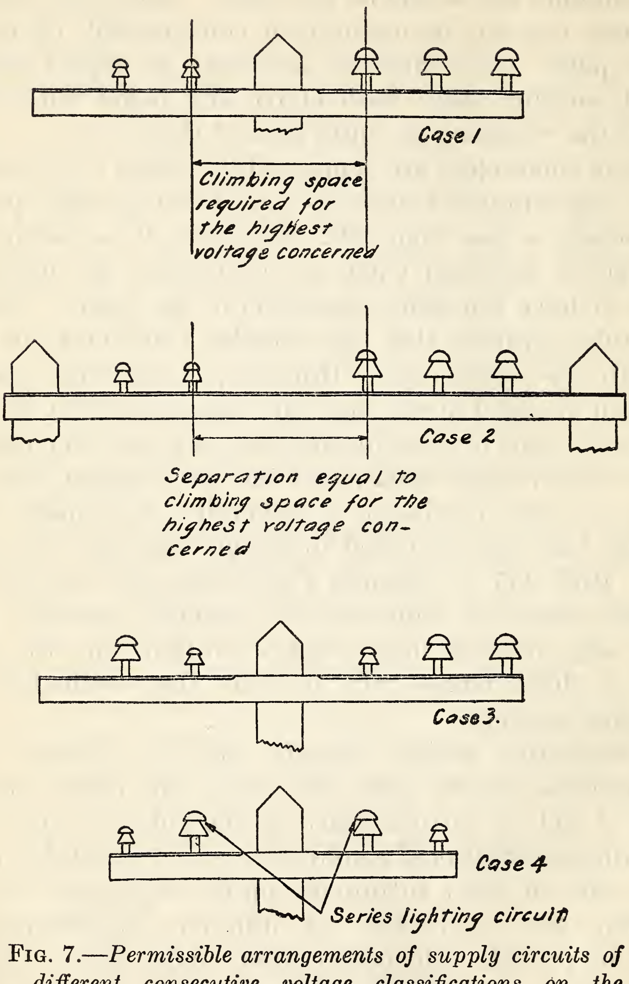

FIG. 7.—*Permissible arrangements of supply circuits of different consecutive voltage classifications on the same cross arm*

munication circuits used in the operation of supply lines. The classification referred to is that of Table 11—750, 7,500, and 15,000 volts being the division points between classes.

The arrangement of conductors shown in case 4, Figure 7, is not permitted for ordinary constant-voltage distributing circuits, but is intended to provide only for series lighting and similar circuits which are normally dead during the day and which would, therefore, not present a hazard to men working on the lower-potential circuits beyond them during daylight hours. Where it is customary to test the series arc circuits during the daytime, it may not be advisable to employ this type of construction unless the workmen take the proper precautions.

236. Climbing Space.

D. Location of supply apparatus relative to climbing space.—See discussion of rule 286, B.

E. Climbing space through conductors on cross arms.—The same climbing space is to be maintained for communication conductors as is required for supply conductors immediately above them when both are attached to the same pole. This requirement is made not so much for the hazard due to the communication conductors alone, but for the hazard that might exist if a fallen supply conductor at some distant point were in contact with one of the communication conductors. In this case a high potential might exist between the two pole conductors of the communication circuit which could cause a serious accident to a lineman required to crowd through conductors having a reduced climbing space. Other considerations are that supply linemen will not get their feet against communication wires; and that they will not injure them in climbing through.

Wherever a primary supply circuit is so installed on the same poles with communication conductors as to provide sufficient space for the installation of a secondary arm between the two, the intent of the rule is met if the communication conductors have a spacing at the poles corresponding to the secondary voltage. This is particularly true in urban territory. However, where the separation between the primary and communication arms is not sufficient for the insertion of a lower-voltage arm, the climbing space through the communication conductors should correspond to the primary voltage.

Communication linemen, in general, are not accustomed to working near supply conductors. It is therefore desirable to allow liberal free working space for these linemen when communication conductors are on the same structure as supply conductors and are above them. This will tend to avoid accidental contact with supply conductors when the lineman's attention is on his own wires.

Telephone linemen are accustomed to handling both sides of the circuit at once and are a great deal more careless as far as voltage of wires is concerned than power linemen. A shock of 150 volts or less usually will not do much harm, but a shock from a greater voltage would be more liable to knock the lineman off the pole or shock him seriously.

In those instances where poles are not climbed while the wires are alive the clear climbing space may be reduced to 24 inches, since that will afford sufficient space for a man to climb if contact with the conductors at its boundaries is rendered harmless.

G. Climbing space for longitudinal runs.—It has become common practice in some localities to place the low-voltage conductors, which are generally used for supplying services, vertically on racks or brackets, close to the poles, thus practically cutting the climbing space in half. While such construction provides comparatively easy and simple methods for the attachment of services, it requires readjustment of other construction to avoid obstructing the workmen climbing up and down the pole and, unless other arrangements in the locations of the adjacent conductors are made, constitutes a hazard. In order to comply with the provisions of the rules without variation, these racks are occasionally placed on extension pieces. In lieu of this, the

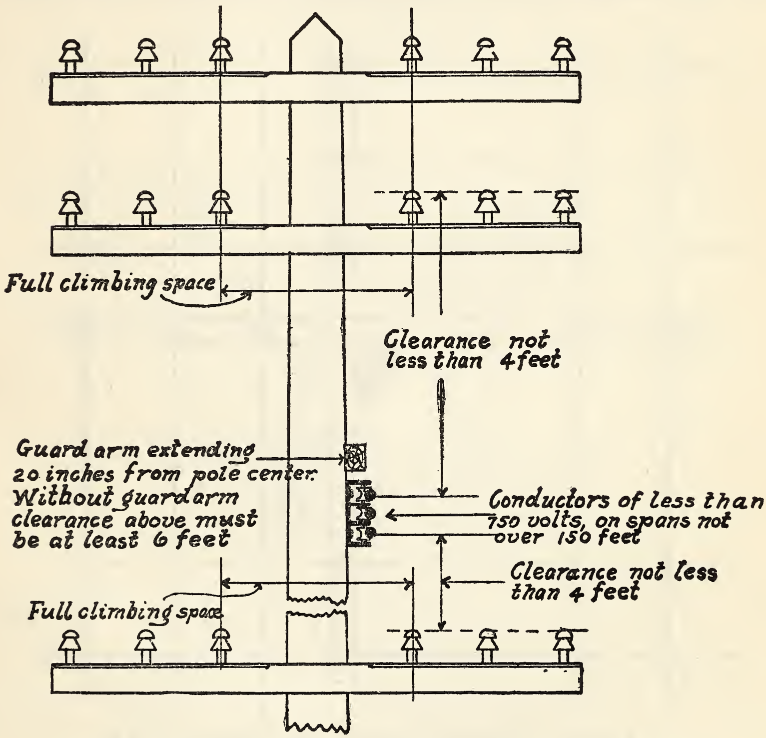

FIG. 8.—*Clearances for conductors arranged on vertical racks*

nearest cross arm may be 4 feet from the rack, or the conductors on the adjacent arms may be so installed as to provide the full climbing space on one side of the rack, thus making it easier for the workman to worm through. Where attachment of conductors close to the pole seems advisable, they should generally be on one side of the pole only for uniformity, and the climbing space should generally be carried vertically at the other side. The climbing space between any two wires is required, hovewer, by the rule, to be carried vertically at least 4 feet above and below them, and any shifting of the climbing space from side to side must,

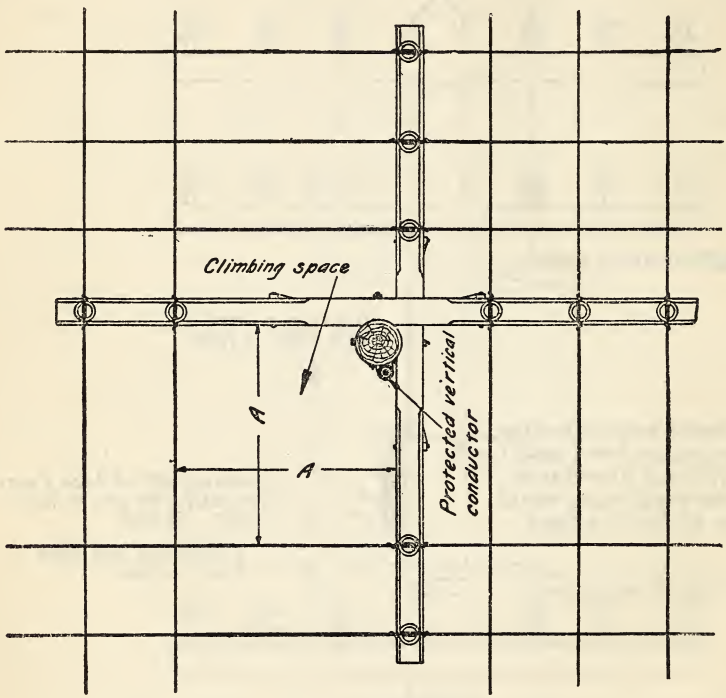

Fig. 9.—*Example of unobstructed climbing space*

therefore, be done in steps not less than 4 feet apart. (See fig. 8.)

H. Climbing space past vertical conductors.—This rule is to show that when the climbing space is changed from one side to a corner of the pole, as illustrated in Figure 9, the pole itself, or conductors inclosed in a conduit or protected by a molding when located in the corner of the climbing space, are not considered as an obstruction.

237. Lateral Working Space.

To safely work upon the conductors supported by a pole or structure sufficient clear working space must be provided between the conductors supported on adjacent cross arms. In order to avoid placing taller poles, thus providing an opportunity for more clearances, it sometimes happens that a utility does not provide this working space between

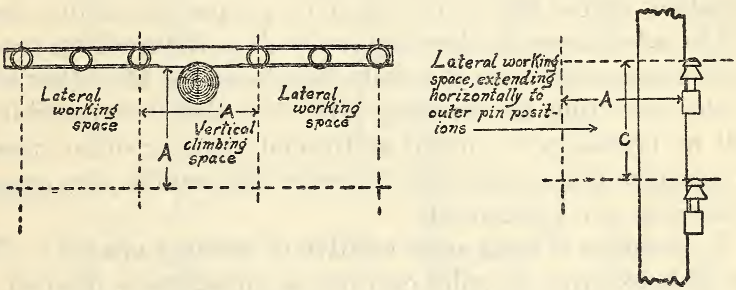

FIG. 10.—*Vertical separation and lateral working space*

A to be not less than 30 inches when supply conductors exceed 300 volts and not less than 24 inches when all supply conductors are less than 300 volts.

C to be not less than values given in Table 11, rule 238, with a minimum of 2 feet.

cross arms. Such reduced clearances greatly increase the hazards. The lineman is forced into strained attitudes, and upon the slightest relaxation of vigilance he may come into contact with conductors operating at dangerous voltages. Liberal working space is an aid to better and more rapid work, since the lineman is able to give more attention to his work and less to his personal safety and to the placing of temporary protective devices before he can safely proceed with work. (See fig. 10.)

The vertical and horizontal clearances called for in the rules are generally between conductors rather than between pins or cross arms. However, in cases where the cross arms fulfill the vertical clearance requirements, but owing to the use of different types or sizes of insulators or different manners of attachment the clearances between the conductors themselves are slightly reduced, the requirements of the rule will be considered as having been met.

The requirements of this rule are important merely to insure that the proper dimensions of the working space are maintained at all times. During reconstruction or when new apparatus, such as a transformer or switch, is being installed, unless the matter is given proper attention, there will be a tendency to place taps or leads in the working space. Such connections can generally be placed on the other side of the pole from the working side, or if this is impossible it will be necessary to install additional arms or other means to support the conductors in order to provide the proper clearances and separations.

D. Location of buck arms relative to working spaces.—The use of buck arms on poles carrying a considerable number of wires offers difficulties to the provision of normal climbing and working spaces and some concessions have been made in the rules in order to make their use practicable. Even though a pole were specially designed to provide the normal clearances, general levels would be disturbed where the buck arms were numerous, as at a junction pole.

The rules require the provision of climbing space, in accordance with rule 236, under all circumstances. To accomplish this, exception is made by rule 236, F, to the general requirement for horizontal separation of wires at supports, under certain conditions. The previous edition of this code permitted a single buck arm to encroach upon the normal working space where primary voltages were involved. This permission has now been modified by requiring at least 18 inches (instead of 24) either above or below the buck arm for any number of buck arms, provided the voltage does not exceed 7,500 volts. For voltages higher than this no concessions are made. To utilize this permission for 2,300 or 6,600 volt circuits, whose cross arms have the usual 2-foot spacing, the buck arm is not placed midway between the line arms but is placed close to one of the line arms, as shown in Figure 11. This should be the line arm carrying the conductors which are connected to conductors on the buck arm.

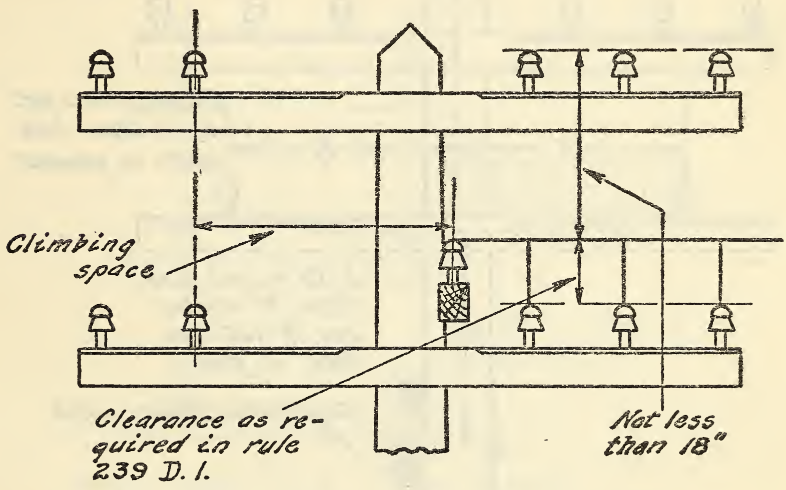

Fig. 11.—*Obstruction of working space by buckarm*

The vertical and lateral conductors will then not obstruct the free 18-inch space which constitutes a reduced working space. One set of conductors can be worked on from below and the other from above.

238. Vertical Separation between Line Conductors, Cables, and Equipment Located at Different Levels on the Same Pole or Structure

A. Vertical separations between horizontal cross arms.—It will be noted that the vertical separations for high-voltage conductors when operated by different utilities is greater than when operated by the same utility. The lack of familiarity of the employees of one company with the property of the other necessitates a greater separation in order to prevent accident.

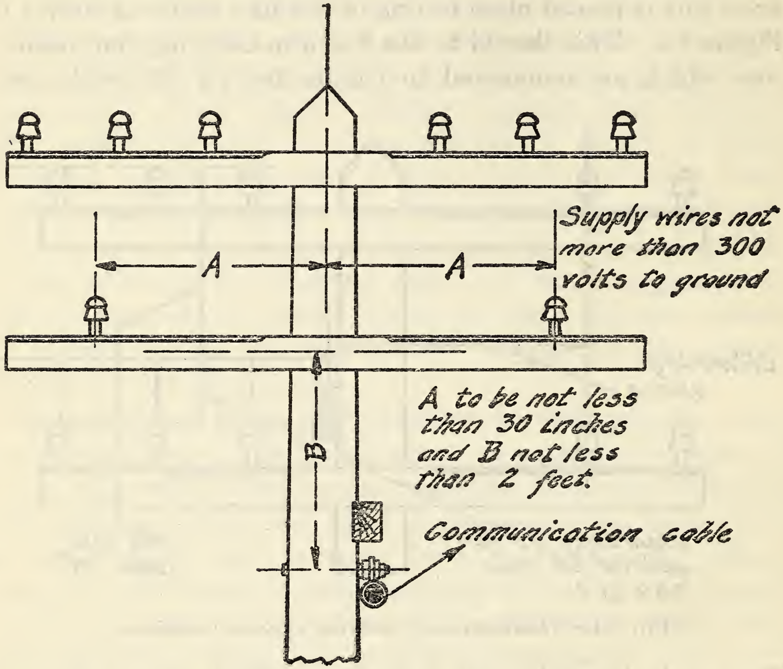

FIG. 12.—*Permissible construction for supply conductors above communication cables*

It may be necessary to increase these vertical clearances under some conditions, as, for instance, when the conductors on different arms are strung with widely different sags. See discussion of rule 238, B. The values given in Table 11 are minimum values, except as noted in the notes to the table.

Where a communication cable is concerned, it is often desired to install it less than 4 feet from the nearest supply arm. Note *b* under Table 11 provides a minimum separation of 2 feet under these conditions, providing the nearest supply conductor is 30 inches horizontally from the center of the pole. (See fig. 12.)

B. Vertical separation between line conductors on horizontal cross arms.—When supply conductors of the same circuit are arranged vertically on separate cross arms, the vertical separations are determined by the highest voltage concerned.

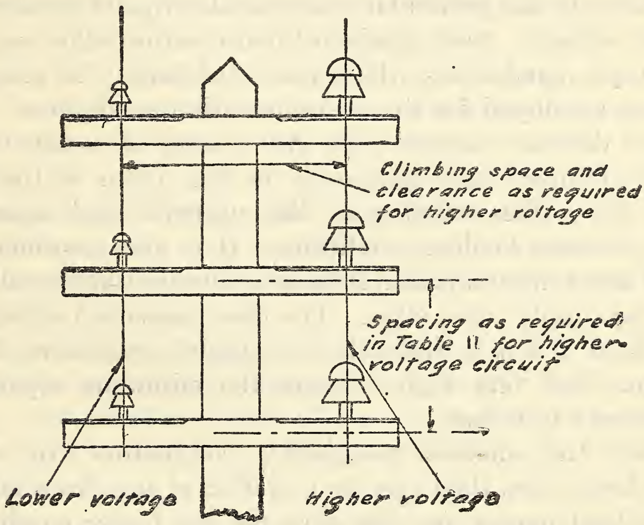

FIG. 13.—*Vertical arrangement of circuits*

This is very logical, as hazard depends on the voltage, and the clearances should be governed accordingly.

While Table 11 requires in some cases a greater vertical spacing between conductors in different consecutive voltage classifications than between conductors of the higher voltage, it should not be interpreted as applying to the condition shown in Figure 13, where the conductors of different voltages are on opposite sides of the pole. In this arrangement the vertical spacing is that for the higher voltage.

The clearances between the two classes of conductors occupying joint poles should receive more attention than where such conductors occupy separate, nonconflicting structures. A minimum separation of 4 feet between communication and supply conductors has been generally considered a proper figure. The supply wires, which are placed at higher levels than communication conductors, are required to conform to a grade of construction determined by the conditions in the particular case considered, and particularly by the voltage. Such grades of construction allow sags for the supply conductors which are considerably in excess of the sags employed for the communication conductors. The vertical distance between the two classes of conductors is thereby reduced very materially in the center of the span below the values existing at the supports and especially under extreme loading conditions. It is also customary to install new communication conductors under these conditions with the supply wires alive. For these reasons a separation of at least 4 feet is desirable for supply conductors of any voltage. For very high voltages the minimum separation is increased to 6 feet.

Where the smallest permissible conductors are strung above large ones, their greater variation of sags from no load to full load makes any less sags for the larger conductors than those required by Appendix A particularly dangerous. The smaller conductors will have about the same ultimate sag under full ice load whether initially strung with the small sag or not, while the larger conductors will increase their sags comparatively little with the ice load. This is one of the reasons (see tables of Appendix A) for recommending larger sags for large conductors than would be necessary if their strengths alone were considered, in order that the smaller conductors if placed above them, as is frequently the case, can be given sufficiently large initial sags to make their variation of sag under increased load moderate. (See discussion of rule 261, F.)

Where direct-current feeder circuits of voltages in excess of 750 volts to ground are installed above communication conductors, particular attention should be given the sags. On account of their size and weight they are often given large sags, as it is somewhat difficult to dead end them under some conditions. Consequently the vertical separation between these trolley feeders and communication conductors at the supports should be increased over what is usually provided for supply conductors of equal voltage.

3. *Conductors of different sags on same support.*

(*b*) READJUSTMENT OF SAGS.

Repeated wind and ice storms will stretch soft copper beyond its yield point, and thus permanently increase the sag. When these sags are increased sufficiently to reduce the clearances as specified in 3 (*a*), they should be readjusted to comply with this rule.

It has been suggested by some engineers that in no case should the cross arm spacing be less than 24 inches, but in many cases it will admittedly be impracticable to provide this much, and in such cases a minimum of 12 inches is permitted.

239. Clearances of Vertical and Lateral Conductors from Other Wires and Surfaces on the Same Support.

A. Location of vertical or lateral conductors relative to climbing spaces, working spaces, and pole steps.—To facilitate uniformity in the arrangement of conductors and equipment on a pole, it is usual to designate one semicircumference or quadrant of the pole as the climbing space. Where poles are used jointly by supply and communication conductors, it is customary to designate the sidewalk as the climbing side, leaving the street side clear for the attachment of lamp leads, and, where a street railway is concerned also, for the attachment of span wires or brackets. Climbing on either the street or the sidewalk side also causes much less swaying of the pole with the consequent swinging of the wires, thereby lessening the liability of the wires coming together where sags are large. At some distance below the lowest cross arm, however, it is necessary to make the climbing space either on the cross arm face of the pole or on the other face, usually the latter.

It is vitally important that this space be kept free of obstructions, such as vertical or lateral conductors or other wires, unless inclosed in conduit or other protective covering. Where such conductors are alive, the hazards to linemen are greatly increased, and in any event the danger due to crowding past the obstructions and coming in contact with live conductors on either side of the climbing space is increased.

B. Conductors not in conduit.—Conductors not in conduit naturally require necessary clearances from other live conductors, from grounded surfaces, or from surfaces of structures.

C. Mechanical protection near ground.—Grounding wires that have become broken by traffic or other cause have lost their effectiveness in protecting the circuits or apparatus to which they are connected. Thus a mechanical protection is very essential to guard against such an accident.

A person coming in contact with a grounding wire when discharging current to the ground will receive a shock, the severity depending on the resistance between ground plate and the earth, also upon the resistance between the person and the earth. Thus, an insulating covering is necessary as a protection for grounding wires, especially when connected to lightning arresters. An iron or steel pipe inclosing a grounding wire would act as a choke coil, thus making the wire ineffective in dissipating surges. (See fig. 14.)

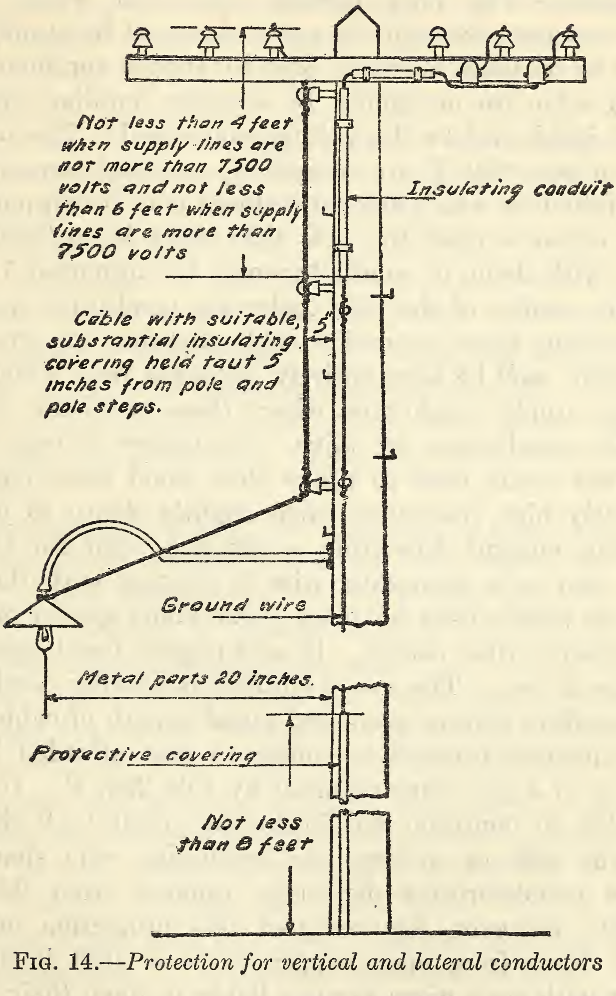

FIG. 14.—*Protection for vertical and lateral conductors*

D. Requirements for vertical and lateral supply conductors on supply line poles or within supply space on jointly used poles.—The only persons concerned when supply conductors pass through the space occupied by supply conductors or on poles occupied only by supply conductors are linemen who are or should be entirely familiar with the hazards incidental to the voltage concerned. The requirements of rule 239, F are, therefore, modified somewhat in that conductors which are not inclosed may be supported at such a distance from the pole that there is no liability of contact with them, or conductors may be supported 5 inches from the surface of the pole under the conditions specified.

Grounding wires, grounded cable sheaths, and grounded guys might well be kept entirely insulated from wood poles carrying supply conductors where these poles are climbed while the conductors are alive. A number of tests which have been made tend to prove that wood poles have not sufficiently high resistance when slightly damp to prevent dangerous current flow from a climber's spur for at least several feet to a grounding wire in contact with the pole. Of woods widely used for poles, some kinds appear of much less resistance than others. In arid regions the danger from wet poles is less. The use of suitable insulating conduit for the grounding wire or grounded metal sheath of cable offers to the lineman protection similar to that afforded by the insulator of a guy wire required by rule 283, B. It seems preferable to continue this insulating conduit all the way down the pole or to keep the grounding wire spaced on suitable nonabsorptive dielectric supports from the pole. The rule, however, has required this protection only far enough down from open supply wires so that linemen in contact with such wires are not liable to have their feet or spurs in direct contact with the grounding wire or cable sheath.

F. Requirements for vertical supply conductors passing through communication space on jointly used poles.—Vertical supply conductors carried through a space occupied by communication conductors require special protection, especially where the voltage is high. Linemen who make repairs or extensions to communication circuits are generally not familiar with the hazards incidental to high-voltage supply lines, and the latter must, therefore, be protected where they are liable to be touched by such linemen. The distance to which the insulating inclosure extends below the communication conductors is determined by the position of the lineman's spur when working on the wires. The upper end of the inclosure is determined by the minimum separations between supply and communication cross arms. (See rule 238, A.) Where the voltage is low, this distance may be as little as 2 feet under some conditions, as provided in Table 11, note *b*.

An insulating conduit for such conductors is to be preferred to an insulating covering of the conductor permitted by the rule in certain instances. The latter may be more readily injured by workmen or become deteriorated by atmospheric conditions, thus producing a hazard.

Where street-lighting circuits or low-voltage services are concerned, the former being alive only during the night time and the voltages being those which are ordinarily handled by linemen, the inclosure specified above may be omitted, providing the conductors are insulated and properly supported, so that a lineman climbing the pole will be able to do so without touching the conductors. This is particularly true where pole steps are installed on poles carrying such conductors. The distance specified, 5 inches, is considered sufficient to permit good footholds or handholds and still prevent contact with poorly protected wires. The specified distance should, however, be maintained to its full value. Supports moderately close together will assist in doing this.

G. Requirements for vertical communication conductors passing through supply space on jointly used poles.—Communication conductors passing through a space occupied by supply conductors require an insulating protection because they are practically grounded and therefore are hazardous to supply linemen.

Sec. 24. GRADES OF CONSTRUCTION

240. General.

While a certain danger results from the existence of overhead lines in any location, an added risk of personal injury is caused by the crossing of a supply line over a communication line, or vice versa, by crossings of one supply system over another and by crossings of supply or communication lines over a railway. In urban districts the hazard from fallen wires is presented to many more persons than in rural districts. Superior construction should be provided where these special conditions exist to reduce the hazards as much as practicable.

One element of hazard due to the existence of an overhead line is dependent on the voltage of the line. For the purpose of discriminating with respect to this element of hazard supply conductors have been divided into various classes according to the voltage concerned. Wherever the voltage enters as a consideration in the various rules, the voltage limits are actually stated rather than merely to refer to a voltage classification, which properly varies with the nature of the rule. In this manner the limits within which the rules are operative are made clear and freed from ambiguity.

If a heavy telephone lead is involved at a crossing, or joint use of poles, under supply wires, the falling upon the former of a high-voltage supply conductor may spread trouble over a wide area. The high voltage may be brought into several telephone exchanges and many subscribers' residences thus bringing danger to many persons. Some protection is afforded, of course, by the telephone arresters and fuses, this protection being very reliable within more or less definite voltage limits, which limits are, however, less than the operating voltage of some of the existing systems of distribution in large cities and much less than almost all transmission voltages. Even at moderate primary voltages, crosses between communication circuits and supply circuits of large capacity may be dangerous unless the resistance of the ground connection of protectors is quite low.

The failure of one supply conductor crossing or on common poles above another will usually subject the equipment of the lower-voltage system to abnormal electrical strain. Should this cause failures of low-voltage apparatus or wiring, operatives and consumers are exposed to conditions with which they are not familiar and which they are not prepared to meet.

Supply or communication lines crossing above steam railroads may cause various hazards. Trainmen know certain hazardous locations, such as low-roofed tunnels and low bridges crossing over the tracks. These obstructions are readily perceived from a distance on account of their size and outline, while a wire is hard to see at a distance. A wire stretched over railroad tracks should always have such a clearance as to assure a trainman that he will not be swept from the roof of a moving car nor caused to fall due to an electrical shock, even under extreme weather conditions when wires are loaded with ice, and thus lowered by stretching. Furthermore, the falling of any conductor across the signal wires used for controlling train movements may cause serious accidents through inability to use the signal system. Adequate strength as indicated in the succeeding rules is therefore necessary to maintain the clearances specified.

In urban districts the greater number of persons constantly exposed to fallen conductors calls for additional consideration. A fallen conductor in a location having a population of 1,000 persons per square mile is obviously introducing a greater exposure than the same fallen conductor where the population is but 10 per square mile. A study of recorded accidental failures of conductors shows that conductors which fall directly within reach from the ground, or so as to involve other circuits, are a far too prolific cause of accident.

Different requirements are properly made to alleviate different degrees of hazard. For supply lines four different degrees of hazard are recognized with corresponding gradations in the minimum standard for construction, and these differences apply mainly to the strength of the supporting structures. The grades are designated as A, B, C, and N, and three of these grades must meet definite strength requirements which are greater than those required for grade N. Grade N is a new designation for construction not required to meet the other grades. Grade A represents the strongest construction. For communication lines in certain locations two additional degrees of hazard are recognized, and the corresponding grades of construction are designated as D and E. Grade D is the stronger of the two.

The required strength construction for the various grades is specified in section 26.

While some communities have in the past seen fit to set fixed limits to the voltage carried by overhead lines within their territory, many of these limitations have been raised or rescinded, and it has seemed undesirable to include such limitations in these safety rules, as such a restriction might sometimes tend to delay useful extension of electrical service and so introduce or continue in use more hazardous light and power agencies.

No requirements for provision of insulating coverings for conductors in overhead lines of any voltage have been made.

While such coverings are sometimes an aid in preventing burn outs, the reduction of hazard derived from their use is problematical. Their use may even cause an added hazard for the higher voltages, as after being in service some years they deteriorate. Their use in this condition gives rise to a false feeling of security. Much more reliable and effective safeguards against the danger from fallen and crossed wires are the provision of proper wire clearances and separations and the maintenance of these clearances and separations by suitable minimum conductor sizes, sags, and strength of supports.

These facts have been kept in mind in discriminating as to the grades of construction required for supply lines where communication circuits are involved.

241. Application of grades of construction to different situations.

A. Supply cables.—Where the conductors of a circuit are all in a cable, well insulated from each other, and inclosed in a grounded metal sheath, the danger of shock from contact is greatly reduced, as is also the likelihood of a high potential on the conductors being communicated to another wire coming in contact with the metal sheath. Such conductors are consequently not required to be of as high a grade of construction as open high-voltage wires. For fuller discussion of this subject see rule 261, G.

D. At crossings.—When an overhead line crosses in one span over two other lines the hazard involved depends not only upon the contact of the higher wire with one of the others, but there is a possibility that by falling upon both, the two lines crossed may be brought into electrical connection. The grade of construction required for the higher line is not less than that required if one of the lower lines crossed the other, since the same possibilities are involved.

E. Conflicts.—In this edition of the code a distinction has been made between conductor conflict and structure conflict, as will be seen by referring to the definitions. As previously defined, a conflict was a structure conflict, and its existence imposed requirements upon all conductors carried by the conflicting structure. Now, a structure conflict imposes requirements only upon the supporting structure and not upon those conductors not involved in the conflict. Conversely, if a conductor alone is conflicting, only it is thereby required to meet the corresponding obligations, and the structure which carries it may be of a lower grade.

242. Grades of Construction for Conductors.

It must be understood that the several parts of a pole structure (structure including cross arms, pins, and insulators) may comply with several different grades of construction; also that different wires or sets of wires on the same pole line may have to meet the requirements of different grades as to minimum sizes and sags.

For reasons already stated (see 240) a distinction is made in the requirements in urban districts and in rural districts. In each case the degree of hazard is determined by the voltage of the circuits concerned, and, when circuits of different voltage are placed on the same supporting structure by the arrangement of the circuits with respect to each other. After much study supply lines, where not exposing communication lines or crossing railways, have been divided into three groups, namely, those of more than 7,500 volts, those of voltages between 7,500 and 750, and those of less than 750 volts. The voltage gradations closely coincide with those contained in the orders of some of the State commissions and have met wide approval among electrical engineers. They have been selected with a view to avoiding voltage regions used in commercial operations, so that a case is not likely to arise where, owing to the drop of voltage along a line, one end of the circuit might be placed in one group and the other end of the circuit in a different group.

When lines are upon private rights of way the hazards to the public are greatly reduced as compared with lines upon public highways. Only trespassers are likely to be injured in case such lines come down, and consequently it does not seem reasonable to make the same requirements for such lines as for those in public places.

A. Status of constant-current circuits.—Constant-current circuits, where above streets and alleys in urban districts, cause the same general hazards to traffic below, or to other supply circuits near them and at lower levels, as do other supply circuits of the same voltage. Under such conditions, therefore, the same grade of construction is called for. Where such circuits, however, expose communication conductors by crossing above, conflicting with, or being located above and on the same poles with the communication conductors, the hazards caused to the communication conductors as at present protected are very different from those caused by constant-potential supply wires of equal voltage. The fusing of existing types of telephone protectors has been made heavy enough to prevent their blowing by contact of the communication circuits with the common types of constant-current circuit, in which current does not exceed 7.5 amperes, and the arrester will, in general, withstand discharge up to this limit. A ground resistance of even 15 ohms will not then raise the voltage at the telephone instrument high enough to present a serious hazard. On the other hand, were it feasible to fuse the protectors with larger fuses and to provide arresters capable of withstanding larger discharges the danger to subscribers from constant-potential circuits would be increased. It is therefore necessary to limit closely the size of the fuse. If, however, the fuse should blow, the inductive character of the series circuit might sustain an arc and endanger both subscriber and property.

B. Status of railway feeders and trolley contact conductors.—Since the hazards of supply wires are due to the voltages at which they operate, for the same reason a trolley feeder must be considered hazardous. This is particularly true where the trolley feeder is bare and placed below communication conductors on joint-pole construction. This position is practically necessary on account of the relatively greater sag of the feeder and to avoid vertical runs through communication conductors. A fallen communication conductor may in this case cause a great deal of damage. The necessary climbing space should be provided in spite of the extra cross-arm strength and bracing required by the usually heavy feeders.

D. Status of fire-alarm conductors.—It was decided that for spans up to 150 feet the minimum sizes and sags given for communication wires crossing over main railroads would give ample safety to fire-alarm lines. However, since it is necessary that fire-alarm wires do not break, especially in cold or stormy weather when fires are most frequent, it is recommended that they be strung with sags considerably greater than those specified as minima in rule 262, I.

243. Grades of Supporting Structures.

Where there are a number of sets of conductors on the same pole on different cross arms, the longitudinal strength of the cross arms, pins, and fastenings supporting each set of conductors is determined by the grade of construction required for that particular set, whereas the transverse and longitudinal strength of the supporting structure is determined by the highest grade carried.

Sec. 25. LOADING FOR GRADES A, B, C, D, AND E

250. Loading Map.

The classification of the territory of the United States with respect to ice and wind has been made from information furnished by the United States Weather Bureau, from numerous answers to a circular letter sent out to power and telephone companies, and through information supplied by engineers having experience with electric transmission in various sections of the country. From the information thus obtained the country was divided into the loading districts shown by the map.

Two principal changes have been made in the boundaries which define the three loading districts. The western boundary of the heavy loading district has been shifted eastward, so that the entire State of Montana and a considerable portion of Wyoming are now in medium loading territory. Otherwise the boundary lines follow the same general course as before, but they have been made to follow more closely the natural physical dividing lines and also the lines dividing the political subdivisions of the various States. It is thought that this will make application of the rules easier for the authorities having jurisdiction and will make it possible in locations near the boundary lines to determine whether a particular structure is in one or another district. Where mountain ranges and river courses are followed, there is less likelihood that a particular line will cross the boundary.

It is fully recognized that weather conditions do not change abruptly at the points which have been fixed as the boundaries of the several districts. The changes from conditions which call for one loading specification to those which call for another are not usually so sudden and do not take place at a definite line but are gradual and are frequently undergoing change from one boundary of a district to the other. Nevertheless, if differences in the weather are to be recognized, a boundary must be located somewhere, and it will sometimes be helpful to locate it more exactly than can be done from the map which is given in Figure 1 (Handbook No. 3). The following description of the boundary lines is consequently given for the benefit of those who may have occasion to trace the boundary more definitely.

The boundary between heavy and medium loading districts has been determined as follows: Starting at the northern boundary line of the United States at the northeast corner of Montana, south along the eastern boundary of Montana to forty-fifth parallel of north latitude, then west to northeast corner of Wyoming; then in a straight line to the most northern point in Wyoming of the Belle Fourche River (north fork of Cheyenne River), then following up the Belle Fourche River to parallel of latitude 44°, then in a straight line to the point of intersection of the one hundred and sixth meridian with parallel of latitude 43° 30′, then south along the one hundred and sixth meridian to the northern boundary of Colorado, then west to the northwest corner of Jackson County, Colo., thence following the eastern boundaries of Routt, Eagle, Pitkin, Gunnison, Saguache, Alamosa, and Costilla Counties in Colorado to the southern boundary of that State; thence following the southern boundary line of Colorado to the Vermejo River; thence following the course of the Vermejo River and the south fork of the Canadian River through New Mexico to Texas; thence following the western and southern boundaries of Oldham County, Tex., and the western boundary of Randall County to Prairie Dog Creek; thence following Prairie Dog Creek and Red River to the mouth of Little River in Arkansas; from this point following the arc of a great circle to a point on the Mississippi River at the boundary line between Tennessee and Mississippi; thence east from the Mississippi River along the southern boundary line of Tennessee and North Carolina to Scotland County, N. C.; thence following the southern boundaries of the counties of Richmond, Moore, Harnett, Johnston, Wilson, Edgecombe, Halifax, Northampton, Hartford, and Gates, in North Carolina, to the boundary line of Virginia; thence east along the southern boundary of Virginia to the Atlantic Ocean.

The boundary between medium and light loading territory is not given in detail for the States of California and Nevada, since State commissions in those States have already carried out local districting.

From Nevada eastward the line has been located as follows: Starting with the Colorado River on the boundary between Nevada and Arizona at 36° of north latitude, due east until the Colorado River is again intersected; then following up the Colorado River to the mouth of Diamond Creek and up Diamond Creek to its intersection with the western boundary of Coconino County, then following the western boundaries of Coconino and Gila Counties south to the thirty-third parallel of north latitude; east along the thirty-third parallel to the Rio Grande, following Rio Grande to thirty-second parallel; east along thirty-second parallel to Pecos River, following Pecos River to thirty-first parallel; east along thirty-first parallel to Tyler County, Tex.; thence following the northern boundaries of Tyler and Jasper Counties to Sabine County; thence following the western and northern boundary lines of Sabine County, Tex., to the Sabine River; thence following the Sabine River northward to De Soto County, La.; thence following the northern boundary of Sabine, Natchitoches, Winn, and Caldwell Counties, in Louisiana, to the Boeuf River; thence along the Boeuf River to the thirty-third parallel of latitude; thence due east along the thirty-third parallel through the

States of Mississippi, Alabama, Georgia, and South Carolina to the Atlantic Ocean.

Light-loading territory shall constitute that region of the United States to the west and south of the last-described boundary line.

251. Assumed Weather Conditions.

The stress in a conductor depends upon the pressure of the wind, upon the thickness of the ice coating carried by the wire, and upon the changes in temperature which affect the conductor length and so change its stress if the supports are fixed. These three factors occur in varying combinations in different districts and vary from day to day in the same district. Weather records show that wind velocities of over 80 miles per hour sometimes occur in districts where ice accumulations over one-half inch thick and low temperature are frequent. On the other hand, other districts exist where winds exceeding 40 miles per hour are unknown and where ice or very low temperatures do not occur.

In this connection it must be pointed out that the maximum velocities recorded by most of the observing stations of the United States Weather Bureau are taken over a period of five minutes and do not register the maximum values attained in gusts of short duration which for several seconds may have velocities far in excess of the average recorded for any five-minute period. A few of the observing stations are provided with instruments giving records of instantaneous values. The instantaneous maxima are found to be considerably in excess of the five-minute averages for the same stations. Moreover, the Weather Bureau stations are for the most part located in cities and towns which are usually in low altitudes and often sheltered, and therefore do not give a fair indication of conditions which are likely to prevail in the more exposed regions. Buildings, trees, and other obstructions reduce the velocities recorded by the instruments and also reduce the pressure upon overhead wires in these locations. On the other hand, overhead lines are usually nearer the earth's surface than Weather Bureau stations. For moderate wind velocities this usually means that the winds are less violent, and definite relationships have been published showing how wind velocity increases with distance above the earth's surface. There is good reason to believe that this relationship no longer holds for the wind velocities experienced during storm conditions. The variation with altitude during such conditions is irregular. Observations at times have shown the velocity to increase with altitude and at other times have shown it to decrease. Under the conditions when the load upon the line may be greatest it can not, therefore, be assumed that the wind velocity at the wires will be any less than at the location of the weather observers' instruments.

The rule makes only three gradations of loading, and it will be obvious that different degrees of strength are required in the three districts.

The loadings specified for the several localities are not intended to represent the actual pressures and loadings to be encountered in those particular regions, nor can the relative values of the loadings be expected to conform to the assumed values given in these rules. They are, however, quantities chosen after careful consideration of local weather conditions for use in making computations of working stresses. The assumed loadings are not chosen to represent the most severe conditions which are likely to be encountered in the various locations, but are values which have been selected after full consideration of present accepted practice and of the several influences which tend to modify or diminish the stresses which might be expected to result from the actual loadings.

The specification for heavy loading remains in this edition the same as before, but the assumed conditions for medium and light loading districts have been modified and simplified. In the present edition the same weather conditions are assumed in specifying vertical, transverse, and longitudinal loading which before was not the case. The conception of the loading specification is thus simplified and its application made, perhaps, more easy. Medium and light loading are no longer expressed in terms of heavy loading, but are expressed independently as involving a definite thickness of ice and a definite wind pressure. In the case of light loading no ice is assumed, but the wind pressure is taken to be higher than for the other districts. The practical effect of this change will depend upon the size of wire involved. It results, for example, in a larger transverse load for large wires and a smaller transverse load for small wires.

252. Modification of Loading.

The records upon which the territorial divisions are based are from a limited number of stations, and these are for the most part in cities, which are naturally located in the lower altitudes and are often sheltered by surrounding hills and mountains. Without a doubt there are many limited areas, particularly in the medium-loading region which, due to their elevation, exposure, or other local conditions, should rightly be classed in the next higher group. In certain regions bordering on the Great Lakes and on the North Atlantic coast, winds of unusually high velocity are of frequent occurrence and may in some instances warrant the assumption of a loading 50 per cent heavier than that designated as "heavy." On the other hand, many regions included in heavy-loading territory are actually subject only to medium-loading conditions.

In locations where the records of the United States Weather Bureau or other reliable records show that the wind, sleet, and temperature conditions warrant the assumption of transverse pressure or resulting loadings materially different from the values specified for these districts, the specified loading for that particular locality may be suitably modified by the administrative authority having jurisdiction therein.

Detailed local studies may indicate that an entire State should not be classed in one loading district but should be subdivided into two or three. Where a State averages heavy loading, some parts may experience weather which justifies medium loading, while other parts may experience weather so severe as to justify the stipulation of an extra heavy loading more severe than heavy loading. Again, a State which has been classed as medium loading may have certain parts which justify heavy loading and others which justify light loading. Local districting has already been carried out in California and Nevada, and may well be considered in other States which include wide ranges of weather conditions.

Rule 253. Conductor Loading.

As pointed out above, conductor loading for medium and light loading districts has been changed from the previous edition. They are no longer expressed as a fraction of heavy loading, but are expressed independently in accordance with the weather conditions assumed in rule 251

Rule 254. Loads upon Line Supports.

A. Assumed vertical loading.—The specification of vertical loads acting upon line supports remains the same as in the previous edition. The assumed loadings do not represent the most severe conditions recorded by the Weather Bureau and operating companies, but represent conditions that occur more or less frequently. Ice one-half inch thick is frequently exceeded, particularly near the northern and eastern borders of the United States, and on occasions ice has been known to collect to a thickness of 1.5 inches, and even more.

B. Assumed transverse loading.—The transverse loading for heavy loading districts remains the same as in the previous edition except that an allowance has been made for the shielding effect of one wire upon another where fairly close pin spacing is used. This allowance only applies where structures carrying more than 10 wires are concerned, and no attempt is made to fit the conditions accurately in any particular case, but the allowance is made by a fixed percentage.

The shielding effect has been demonstrated both by laboratory experiments and by measurements upon actual structures erected out of doors. Experience, moreover, has indicated its existence, inasmuch as heavily loaded lines have often experienced without failure storms which might have been expected to produce disastrous results if some such element were not involved. Such an allowance is practically equivalent to the assumption of only 5.3 pounds per square foot of wind pressure in heavy and medium loading districts. In light loading districts no such allowance is made, as for usual spacings of wires which do not carry an ice coating the shielding effect would be much less and does not warrant such an allowance.

Here, again, the specifications for medium and light loading are no longer based upon the value for heavy loading, but are expressed independently.

Since flat surfaces offer more resistance to the wind than cylindrical surfaces, a larger pressure must be used in the case of latticed structures or wooden poles which have been sawed square.

6. *Angles.*—Trolley wires on joint poles occasionally produce very heavy transverse stresses in the supporting structures, especially at angles or curves in the line, and,

therefore, require consideration when computing the strength of these structures. The unbalancing effect of a long trolley crane with the conductor is very severe and must be counterbalanced either by side guys, concreting, or setting the pole deeper than usual. The use of double cranes with the structures between the tracks of double-track roads eliminates the unbalance of vertical load, but still requires increased transverse strength on account of the unbalanced conductor tension.

C. **Assumed longitudinal loading.**—The conductor loadings specified in rule 253 determine the maximum tensions to be considered in the conductors which will, of course, obtain at the time when the specified layer of ice and horizontal wind pressure are acting simultaneously. In the case of a dead end, this determines the maximum pull upon the support which is to be taken as the longitudinal loading. At other supports where the conductors continue far beyond the support the tensions in the conductors are approximately balanced unless there is an angle in the line, in which case the resultant will be a transverse load as specified in rule 254, B, 6. In case of wire breakage a longitudinal load will come upon the supporting structure, and such a contingency must be considered in designing the line, at least at those points where failure produces the greatest hazards or where such failures are most likely to occur.

If a line is built of the same grade of construction throughout, it is considered necessary to supply special longitudinal strength only at crossings over other wire lines or over railroads and at the ends of sections involving conflicts or joint use of poles. The assumption made for such cases is that one-third of the conductors may become broken.

At points where there is a change in the grade of construction—as, for example, where a special crossing span has been built in a line which is not so strong elsewhere—it is recognized that a failure in the weaker portion of the line may affect the stronger portion, and hence the longitudinal load at such points is based upon the assumption that all of the wires may become broken. This assumption is, however, modified by putting a limit upon the total load for which the structure need be designed. The larger the number of conductors carried the less the likelihood that all of them will be broken.

In the case of supply conductors, the actual tension in the conductors corresponding to the existing sag is used in the computation of load. In the case of communication conductors, the tension in the conductor is assumed to be one-half its ultimate strength, since such conductors are never given larger sags for the purpose of relieving the pull upon supports as is done with heavy supply conductors.

D. Average span lengths.—In making computations for determining the stresses in the supports of a line of any length where conditions as to height, length of span, loading, etc., are fairly uniform, it is obviously unnecessary to compute each span separately in order to obtain results which are as nearly exact as the various assumptions which must be made. The tensions in the conductors throughout the length of the line tend to equalize themselves when they are installed. It is considered sufficiently accurate to employ an average span as the basis for transverse strength computation with the limitations given. Crossings, which require a special grade of construction, or heavy corners, must necessarily be based upon the length of adjacent spans only.

Tower lines in hilly country, where the span lengths may vary in a ratio as large as 4 to 1, require individual treatment. It is customary, however, for utilities to employ a fairly uniform tower, except at corners or dead ends, this tower being designed to withstand the heaviest loads. Consequently, the average load imposed upon it permits a factor of safety much higher than that for which it was designed.

E. Simultaneous application of loads.—It is usual in designing structures to consider the various loads with which they are concerned as acting simultaneously, and the strength of the structure must be sufficient to withstand the combination of loads. In calculating the transverse strength of poles and towers the transverse and vertical loads are considered to act simultaneously. In view of the rather severe requirements for longitudinal loading the effects of such loads are considered independently. At the same time this greatly simplifies the computation, since the permissible working stresses for longitudinal loads are different from the permissible working stresses for transverse and vertical loads. Where poles are supplied with head guys for carrying the longitudinal load, as will usually be the case, the required guy strength is independent of the vertical and transverse loads, and a distinction comes into effect only where the structure carries the longitudinal load without the assistance of head guys. For communication lines crossing railroads the necessary head guys are specifically stated in rule 262, C, 4, and the question of how the longitudinal load shall be computed does not enter.

Sec. 26. STRENGTH REQUIREMENTS

In section 24 grades of construction have been specified for line conductors and their supports, depending upon the hazards of the situation where they are constructed. All lines must meet certain of the requirements of the code, such as those for clearances. Other requirements depend upon the grade of construction and the differences in the requirements for the different grades are mainly in the item of mechanical strength. They also involve, however, certain other items, such as the electrical strength of insulators.

With regard to some items the requirements are the same for grades A and B, whereas for grade C the requirement will be less or may not be made at all. In this edition grade N is the designation given to construction which does not have to meet the requirements of any of the other grades. There are, however, a few strength requirements for grade N construction, such as limiting sizes for supply conductors.

The mechanical strength of poles and similar structures involves three considerations. They must be able to support the weight of the conductors when carrying sleet or ice of the specified thickness; they must have sufficient strength to withstand the pressure of the wind at right angles to the line; and they must have sufficient strength to withstand the pull in the direction of the line due to any tension in the conductors which is not balanced; as, for instance, at a dead end. (See fig. 15.) The conductors must be strong enough to carry this same tension, which is the resultant of the effect of the transverse wind pressure and of the weight of the conductors loaded with ice. The three elements involved in strength considerations are treated separately in the rules, but in this edition the loading specification has been made the same with respect to all three elements as already stated in section 25.

In the previous edition of this code a definite factor of safety for transverse strength typified the grades of construction A, B, and C. This is no longer the case. The factors of safety for steel supports and for wood poles are no longer the same; and even for one material the factor of safety is sometimes different at crossings and at other parts of the line, such as conflicts, where the grade of construction has the same designation. The factor of safety has also been made different for treated and untreated wood poles in certain situations when installed but no distinction is, of course. made on this account in the replacement values.

260. Preliminary Assumptions.

Certain influences which diminish the effect of the actual loadings have received careful consideration by reducing (below what would otherwise be considered proper) the assumed loadings and associated factors of safety upon which are based the strength requirements of the several

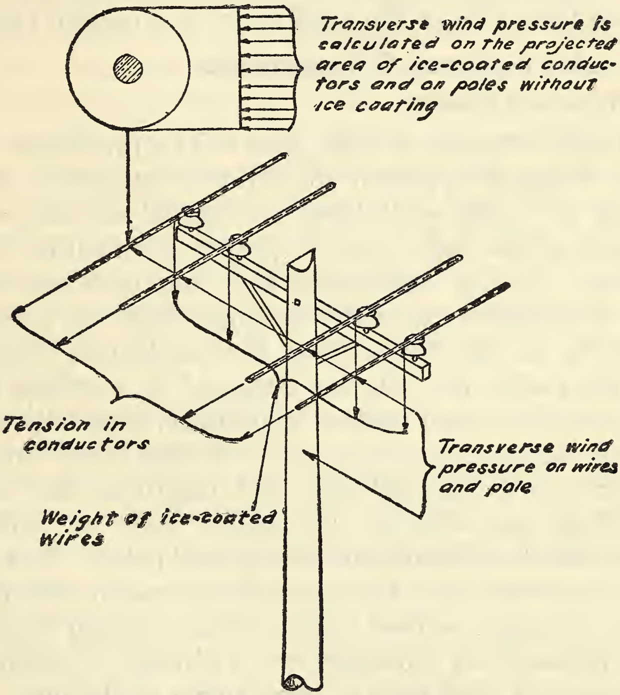

Fig. 15.—*Forces producing load on supporting structures*

parts of the line; namely, conductors, fastenings, and pole or tower structures. The computation of stresses must be made on the assumption that there is no deflection of supporting structures. Such deflections occur, however, especially with wood poles and tend to relieve local strains and distribute the load more uniformly. The conductors themselves exert a powerful influence in distributing the load along the line and aiding the stronger structures to help support weaker ones.

In addition to these items, it must be remembered that the maximum wind pressure and the maximum ice loading seldom occur simultaneously; while surrounding hills, buildings, and trees shelter the conductors to a certain extent.

261. Grades A, B, and C Construction.

A. Poles and towers.

1. *Average strength of three poles.*—The provisions of this rule are designed to permit considerable latitude in the construction of wooden-pole lines. As stated elsewhere in the discussion of the code, there is proper justification for this allowance. It is a well-known fact that each pole in any supply line assists materially in supporting the poles adjacent to it, for the reason that the conductors themselves act as guys after the pole has deflected to a certain extent. This principle is often utilized in practice, especially on lines which are subjected to heavy gusts of wind which are not at all uniformly distributed over the length of the line. A longitudinal guy wire at such places helps to stiffen the line and distribute local loads over several poles. However, it is very important from the standpoint of safety that poles of sufficient strength be used where special strength is required; as, for instance, at crossings over railroads or communication lines or at dead ends or large angles in the line.

Unfortunately proper attention is not always given to this detail, and as the supply of large poles is often not sufficient to allow their use throughout the line the utility often finds that they are not available just at the time when they are most needed on account of poor selection. This point was very aptly brought out in a survey undertaken by the Bureau of Standards to determine whether or not the requirements of the rules governing transverse strength are met in actual practice. It was found that, although there were poles of sufficient size elsewhere in several important pole lines, they were not placed where they were most needed. A proper arrangement of the poles used in the line would have provided ample strength throughout.

Since special requirements are made for crossing spans, compliance with these requirements must be based upon actual pole strengths at the point in question.

2. *Reinforced-concrete poles.*—The construction of reinforced-concrete poles has not reached such a uniformity of practice that the committee felt warranted in prescribing definite allowable stresses as has been done for wood and steel structures. In place of this, factors of safety have been specified so that if the properties of the materials used are known it is possible to proportion the dimensions of the structures with reference to the assumed loads in conformity with this rule.

3. *Steel supporting structures.*

(*c*) MINIMUM STRENGTH.

Steel towers should be so designed that they will withstand, before any conductors are attached, a wind pressure in any direction three times that designated in the loading specification.

(*d*) ALLOWABLE UNIT STRESSES; STEEL.

In this edition definite limiting values for the working stresses for the different grades of construction are stated in the rule, since the allowable stresses in compression are reduced by a multiple of the slenderness ratio in all cases to less than the permissible values in tension. The tensile stress, however, is relatively of little importance in the design of steel towers because the important members including the legs are subject to either compression or tension according to the circumstances and when properly designed for com-

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pression will invariably be found sufficiently strong in tension. Sheer is also of little importance in towers except in bolt and rivet connections for which limiting values of the permissible stress are given.

In adopting limiting values for unit stresses the committee that passed on this matter had in mind steel furnished under either the manufacturers standard specification for structural steel class A, or the standard specifications for structural steel for building of the American Society for Testing Materials. It is recognized that special steels having higher yield points are available and when these are utilized the rule permits a higher working stress. In determining such allowable stresses, the yield point of the standard steel considered in Table 16 is to be taken as 33,000 pounds per square inch in tension and 33,000 pounds minus 100 L/R pounds per square inch for compression. For structural steel having an elastic limit of 45,000 pounds per square inch and in other respects a quality equal to that of the two specifications mentioned above, the yield point in compression may be taken as 45,000 minus 155 L/R pounds per square inch.

(*e*) THICKNESS OF STEEL.

The minimum thicknesses prescribed for galvanized and painted members were selected with proper consideration of standard specifications and the best everyday practice. The extra thickness prescribed for painted members as compared with galvanized members is justified on the ground that painted steel deteriorates, especially along steam railroads where the sulphur from the coal smoke may have a particularly injurious effect. Steel towers and poles should be considered as permanent structures, and the employment of very thin members whould tend to limit their life, expecially under improper maintenance.

(*f*) UNSUPPORTED LENGTH OF COMPRESSION MEMBERS.

The limitations of the ratio of L, the unsupported length of a compression member, to R, the least radius of gyration of the member (sometimes called the slenderness ratio) are based on standard specifications and good practice.

(*h*) ADDITIONAL REQUIREMENT FOR ANCHOR TOWERS.

When steel supports or towers, such as A frames or H structures, which are capable of considerable deflection longitudinally, are used throughout the line, an occasional anchor tower should be used to strengthen the line. In case the conductors in any span should fail, the anchor towers will limit the number of towers that may be destroyed through inability to withstand the unbalanced load caused by the conductors attached to them.

(*j*) PROTECTIVE COVERING OR TREATMENT.

Steel and iron parts of towers and poles are subject to deterioration unless properly protected by galvanizing or some other equally effective treatment, or unless a good coat of weatherproof paint (such as graphite) is maintained. Galvanizing should be done by approved methods and be of such quality as to meet standard specifications, such as have been adopted by the National Electric Light Association and the American Railway Association. The preparation of an American standard is now in the hands of a sectional committee.

4. *Wood poles.*

Wood poles have been almost universally employed up to the present time as supporting structures for distribution throughout the country and are much used for transmission lines also. Considerable anxiety has been felt by public-utility engineers about the future supply of these poles, particularly the larger ones. It is known generally that the source is not inexhaustible, and that some local supplies are already exhausted. Poles are being used at a very rapid rate as the demands for extensions of lines have rapidly increased, and the deterioration of poles now in service has necessitated their replacement in very large numbers. These demands on the pole supply of the country altogether amounted, in 1925, to considerably more than 3,000,000 poles, according to the statistics of the Census Bureau. However, in spite of this rapid cutting of timber, the Forest Service has indicated that, except for one variety of pole, the timber in sight will supply the demand for a great number of years. The blight which is attacking and killing the chestnut trees has made it necessary to cut them very rapidly in order to utilize the wood for poles. In spite of this fact, however, the standing chestnut will provide poles at the present rate of cutting for approximately 10 years.

In order to prepare for the future and to delay the necessity for resorting to other and more expensive supporting structures, the use of preservative treatment for wooden poles is strongly recommended. A number of investigations, covering periods of a great many years, have indicated that the life of poles in the ground is increased by preservative treatment by many years, depending on the kind of wood, type of treatment, and, to some extent, the character of the soil. The advantage of such treatment is therefore evident. There are several different methods for applying the preservative, some of which produce a greater penetration than others and are therefore more effective.

Long before the expiration of the time when it is economically possible to obtain poles for use as supporting structures for electrical supply and communication lines, the present practice of necessity will have to be modified and changed to meet new conditions.

Where lines carried on wood poles are necessarily heavy, it is usually advisable to install poles giving some margin of strength over that required to just meet the rule, and the allowable deterioration may then, of course, be more than given in Appendix F. But where this margin of strength can not be provided, the maintenance of the pole will require earlier attention. Preservative treatment, butt reinforcement, or other methods may be used to maintain the pole to a higher percentage of its initial strength.

The extent of the deterioration of a wood pole is very often difficult of determination. Where the butt has been subjected to insufficient preservative treatment, dry-rot will develop in the interior of the pole, which is not visible from the outside, and while it does not weaken the pole to the extent which butt rot on the outside of the pole weakens it, nevertheless it allows rot to continue much more rapidly than it otherwise would.

Poles are very often stubbed, instead of changed, especially in rural districts. If properly done, the results are effective, for the reason that it is generally possible to secure stubs of much better grade and much cheaper on account of their short length than full-length poles. The wrapping of the joint with wire in addition to bolting is recommended to prevent the bolts pulling through the pole. The stub should be placed beside the pole and not in front of it. (See fig. 16.) It is often advisable to remove the rotted butt of the pole to prevent the decay of the stub by reason of the close proximity of rotted wood. The top of the stub should be cut at an angle and painted with pitch in such a manner as to shed water.

In recent years many substitutes for the stubbing of poles have been tried out, such as the use of concrete reinforcements, metal reinforcements, etc. Opinions differ as to the desirability of the different methods, and it is mainly a matter of economic consideration to determine the greatest return in years of service for a given expenditure in any of these forms.

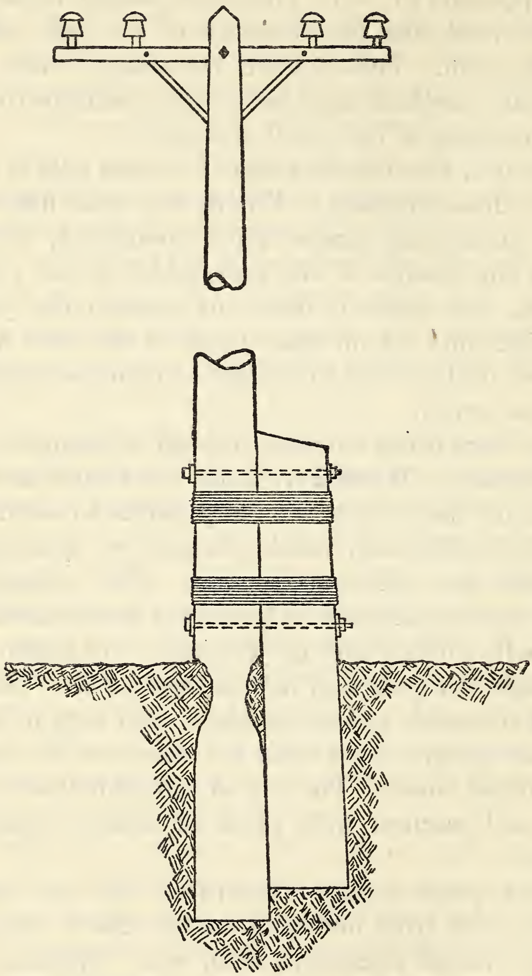

FIG. 16.—*One method of stubbing to reinforce a deteriorated pole*

In attempting to arrive at proper values for the ultimate strength of wood in poles of different varieties, it was found that numerous experimental data were available, a summary of which was made for comparison. From the data thus obtained the maximum allowable fiber stress for various poles was assumed. A figure somewhat lower than the average value of the breaking strength for a given kind of pole was taken in order to insure the majority of poles falling above the assumed strength. It is to be supposed that an occasional pole will fall below the strength specified, but such a pole in a line, when flanked by poles of superior strength in spans of ordinary length, is not likely to fail.

There are, no doubt, lines on every system that require only grade N construction at the time of installation, but due to circuits added later they are then required to conform to the requirements of a higher grade. For example, an 11,000-volt supply line in rural districts would in itself require only grade N, but if a 110-volt circuit were added the line would then be required to comply with grade C construction. If the line were not originally designed for grade C requirements, it will only be by luck that it will conform to that grade after the lower-voltage circuit is added. It would be very expensive to rebuild the line to meet the requirements due to additions made. As it is very possible for many pole lines to change from one grade to another sooner or later, the line should be originally constructed to comply with the grade that may be required of it in the future.

Wood poles should be free from butt rot, heart rot, season checks, wind or ring shakes, ring rot, cat faces, or other natural defects that would materially weaken them.

In no case should the minimum size of poles be less than here specified when grade A, B, or C construction is required. It is necessary to prescribe minimum top diameters to give adequate strength for framing as well as to hold the pole to suitable proportions. The strength of poles is based on ground-line circumferences. This is because of the fact that the ground line, if not originally so, soon becomes, through decay, the weakest section of the pole or the point where failure is most likely to occur. In species of poles having slight tapers the weakest section is always near the ground line, while for poles having excessive tapers or flaring butts the weakest section is initially at some distance above the ground line. However, even in these poles the ground line will generally become the section of least resistance (in proportion to bending moment of load) before they deteriorate to the point of renewal.

Tables giving the moments of resistance of wood poles, the amount of permissible depreciation before replacement expressed in terms of ground-line circumference and diameter, the allowable number of wires on a given size pole with and without side guys, and recommended definite setting of poles are all given in Appendix F.

5. *Transverse-strength requirements for structures where side-guying is required, but can only be installed at a distance.*

At many crossings, especially on city streets, it is not feasible to attach side guys to the crossing poles, and the only other method of meeting the strength requirements would be the use of special structures, such as steel poles or towers. To obviate the additional expense of such construction, the alternative is offered of treating several spans collectively and providing the transverse strength at those poles where side guys can be erected. This treatment is restricted to stretches 800 feet in length, and the intervening line must be of uniform grade in all other respects.

The justification for this alternative rests in the observed fact that the conductors themselves act as guys to the poles and serve to equalize the load in some instances and in others to transfer it to the resisting structures. The guying is not only longitudinal, but as soon as deflection of a pole begins includes a transverse component. Instances are on record where the conductors have held up poles which, without their help, would have fallen.

6. *Longitudinal strength requirements for sections of higher grade in lines of a lower grade of construction.*

(*a*) METHODS OF PROVIDING LONGITUDINAL STRENGTH.

As in rule 261, A, 5, where special alternative construction is at times necessary on account of unusual conditions to provide the required transverse strength, so, for like reasons, a special alternative construction may sometimes be necessary to provide the required longitudinal strength. The occasion for this alternative construction in connection with longitudinal strength does not, however, as often occur for the reason that head guys can generally be installed. Perhaps the principal occasion for its use is the existence at railroad crossings of roads parallel to the railroads. The limiting distance in this case has been made the same as that specified in 261, A, 5.

Either at a crossing or at an end section of high-grade construction the unbalanced tensions may, under certain given conditions, be divided between two or more pole structures, due to their respective deflections toward the crossing section or other section of strong construction. It is ordinarily impracticable to distribute such loads over more than two or three poles, and the pole nearest the weak section or the angle in the line must ordinarily withstand most of the load.

Usually the use of a crossing structure strong enough to withstand the loads, or the transferring of the load to a sufficiently strong and rigid end structure will be found more satisfactory than attempting a distribution of load over two or more structures, each of which alone is too weak for the load imposed. Often the computation of the division of loads between such poles is difficult and may result in unanticipated and dangerous weakness in the crossing or end section span of the presumably strong construction.

When the assumed load can not be carried, it must be reduced by increasing the conductor sags. The object of this rule is to make the section of higher grade independent, so that it may stand even in case of failure of the line at a near-by point. If the entire line is built to the same specifications this is not necessary.

(*b*) FLEXIBLE SUPPORTS.

Where flexible supports are installed, the liberal use of guys in all directions is recommended, provided such guys have the necessary strength and are properly installed. In case guys are freshly installed, an inspection is often necessary after a short time on account of the slight give in the joints of attachments, especially where anchors are employed.

B. Foundations.—That the foundations of steel poles and towers are, as a rule, the weakest feature of the structure is a point on which there seems to be general agreement. The fact that foundations are subject to variations in the character of the soil as well as being affected by moisture and frost, while all other line material is of quite uniform and definitely known properties, is further reason why particular care should be given to them. Good workmanship is of no less importance than proper design. Insufficient tamping of the back fill is a common source of trouble and has been the cause of some failures.

Owing largely to their lower cost, earth foundations have been used extensively. In many parts of the country where lines are in inaccessible regions it is difficult to secure concrete materials without long hauls, and the cost of such foundations would preclude their use. There has been considerable objection to earth foundations, owing to the large number of failures resulting from their use. Failures have occurred on a number of different lines constructed with metal footing and earth back fill, and it has later been found necessary to reinforce them with concrete.

Foundations must, in general, be designed to withstand bearing, uplift, and a lateral force tending to slide or overturn them. The downward force need scarcely if ever be considered, as foundations designed for uplift will invariably develop adequate bearing power. Perhaps one exception to this would be in swampy ground where it may even be necessary to resort to the use of piles to give adequate bearing.

The point has also been made that under the most severe conditions of sleet loading the ground would probably be frozen, but as there is no assurance of this, in general, it must be considered as an additional safety factor rather than a factor affecting design.

The concrete used for tower footings and foundations should be of good quality and proportions. It is a mistake to use a lean concrete on the assumption that its function is merely that of ballast. Not only is the foundation called upon to withstand shearing and bending stresses, but it also acts as a protection to the steel member embedded in it.

C. Guys.—On account of the great flexibility of wood poles they may deflect considerably before developing much resistance to the transverse loads applied. Guys when installed properly are under initial stress and would fail before stretching enough to put much load on the poles. Thus, it is seen that the strength of a pole can not aid a guy, and therefore a guy must take the total load or it would be ineffective.

If attached to a structure not capable of much deflection, the strength of the structure and of the guy are added.

D. Cross arms.—In general, cross arms used in the construction of electrical transmission and distribution systems are made of Douglas fir or yellow pine (either long leaf or short leaf). While other materials are not prohibited, their dimensions must provide the strength called for in other rules.

The minimum cross-arm sizes which have been deemed reasonably adequate vary with the cross-arm length and number of conductors carried, since the length of lever arm and the possible stress due to both vertical and longitudinal (parallel with the line) loads vary with these same factors. The given sizes are those which will withstand with a proper margin of safety a working load due to an unbalanced longitudinal force of 700 pounds on the end pin (which might occur if an outer conductor broke at one side of the cross arm), which is the working load that can be withstood by good wood pins. These cross arms will also withstand with a margin of safety the total vertical load of all conductors under the assumed maximum ice loading up to spans of 300 feet with No. 0000 conductors on all pins. For larger loads larger cross arms or double cross arms are often advisable.

Conductors for overhead lines may, at some one temperature and loading of wind or ice or both, exert balanced forces on pins, cross arms, and poles in tangent sections of pole lines. At other temperatures and loadings the forces will be to some extent unbalanced.

In general, the longitudinal unbalancing will not be severe, except at angles and dead ends unless a conductor fails. By Table 82 of Appendix E it is seen that transverse wind load is unlikely to break conductor fastenings, pins, or cross arms, even with heavy conductors in long spans. The vertical load at times becomes serious for small cross arms, but not for pins.

Through its design the insulator will take its load as a crushing force at the tie groove and is usually amply strong. The insulator pin acts as a beam whose length is equal to the distance from the top of the cross arm to the point of attachment of the tie wire. The cross arm also acts as a beam whose length varies with the conditions, and in the case of a cross arm carrying a single conductor on one side of the pole is equal to the distance from the pin position to the point of attachment at the pole.

2. *Bracing.*—Bracing is, of course, generally necessary to withstand unbalanced vertical loads, as with oscillating conductors, men at work, or line equipment carried on the cross arms. Braces should be attached on front of cross arm.

On many existing poles with inadequate climbing space the men prefer to climb around the ends of the cross arms rather than up the pole. The cross arms should be of sufficient strength to support the weight of a man, in addition to that of the conductors without sleet, with a factor of safety of at least two. This is necessary to provide for deterioration and for the possibility of men working on them when the wires are coated with ice. The practice of climbing a structure by employing the ends of cross arms as steps should be discouraged, particularly where the wire positions of the arms are full.

5. *Double cross arms at angles or dead ends.*—Double cross arms properly blocked should be used at unbalanced corners and dead ends as an extra precaution to provide additional strength and additional conductor fastenings. Double cross-arm construction prevents the cross arm from tilting after being under continual load for long periods of time, which might cause the pin to pull out.

6. *Location.*—The practice of attaching single cross arms on adjacent poles to opposite sides of the poles is to be commended, since it helps considerably to tie the wires in

with the poles, and if a number of wires fail in a span the cross arm on the several adjacent poles will not be pulled off.

E. Pins and conductor fastenings.—In ordinary tangent sections of lines away from crossings it is not contemplated that pins or ties shall be required to withstand broken-conductor loads with the larger sizes of conductors. Up to a No. 4 hard-drawn wire, however, the pin and tie will ordinarily withstand the tension in the conductor at full loading (in this case the same as its yield point, about 750 pounds). For larger sizes conductor failures are comparatively rare, because mechanical qualities are better and wires less frequently swing together or sag into others below.

At corners and dead ends, however, the conductor tensions are normally unbalanced, and the tie must be able to withstand the full force to which the conductor loading can subject it. Double ties to double pins, strain insulators with rope sockets, clamping devices, and similar special arrangements then become necessary for the larger conductors.

The use of metallic pins on the higher-voltage lines employing pin-type insulators is recommended, particularly on account of the deterioration of wooden pins by dry rot or the effect of leakage or corona discharge which may occur under abnormal conditions. Where metallic pins are used, the threaded portion for supporting the insulator should be of a flexible nature or of special design. Insulators mounted directly on threads cut on metal pins will often crack and split. Steel pins have the advantage of using a smaller hole in the arm, and thus conserving the strength of the latter.

The tie wires used to attach the conductor to the insulator, if of the pin type, should be of the same material as the conductor itself, in order to prevent electrolytic action. In other words, aluminum tie wires should be used with aluminum conductors, and so forth. Where aluminum conductors are carried by suspension insulators, they should be protected by a shield of some sort to prevent injury to the conductor and also corrosive action with the clamp.

3. *Height of pin.*—There are many different types of insulator pins and methods of tying a conductor to an insulator. The insulator pin most frequently used in urban districts is the so-called standard locust pin with a diameter of 1 inch at the top and 1.5 inches at the shank, length of shank 4.25 inches, and an over-all length of 9 inches. The results of tests of 495 pins indicate that such pins will normally withstand during a reasonable life the loading due to a tension of 700 to 1,000 pounds in a conductor when applied at the side tie-wire groove of the insulators most generally used, giving a lever arm of 3.5 inches. Pins of greater dimensions for higher-voltage insulators usually have increased lengths for the lever arm, so that the value of loading which causes failure remains fairly constant. Further, the more commonly used ties are limited in their mechanical strength and have a value about equal to that given above for pins.

F. Open supply conductors.

1. *Material.*—One of the greatest hazards to the public from overhead lines is that of fallen wires. The use of noncorroding material for overhead conductors will aid materially in avoiding this hazard.

The use of aluminum without reinforcement as a line conductor should be adopted only after very careful consideration, especially where long spans exist. Aluminum wire, like all other conductors, is continually swayed by the wind between supports. Where it is carried over the usual saddleback of pin-type insulators, it wears away, in spite of the tie wire, and ultimately fails unless it is reinforced. Suspension-type or strain insulators or some special dead-ending devices are recommended under these conditions.

It is recommended by this rule that medium copper be used for new overhead lines rather than soft copper, because so long as copper wire remains soft it will stretch in every considerable storm and endanger wires below, as well as the public, from fallen wires, and will also endanger service, employees, and consumers by the swinging together of the elongated and deeply sagging conductors.

By confining the use of soft copper to the heavier sizes—say, larger than No. 2, including railway feeders—the hazard will be much reduced. Railway feeders in particular are usually so large and in such short spans that to avoid serious stresses on their supports they will not be strung to such small sags as, even with soft copper, will cause serious elongation (exceeding the yield point) under wind and ice loads to be expected.

It is realized that soft copper as now found in existing pole lines is, after a period of use, not as soft as when originally strung but is at various stages between freshly annealed and medium wire according to the length of the time it has been up, the severity of storms to which it has been exposed, and also according to the character of original stringing. This results from the fact that it has never been practicable to give sufficient initial sag to soft copper in small sizes, No. 6 or 4, with its low yield point, to prevent stretch and increase of sag under frequently recurring wind and ice loads. It has been strung to small sags in the expectation of their remaining small enough to keep lines from swinging together. Much of the soft copper now on poles, although it has stretched considerably in storms, is still soft enough to be subject to further dangerous elongation with even moderate and frequently occurring storms. The process of changing soft copper into a safe wire through repeating unsafe elongations and repeated slack pulling seems to be unwarranted. Men are necessarily required to be often on poles pulling slack, or wires will frequently be slack enough to cause more or less danger. In practice, both these undesirable conditions exist in varying degrees.

In spite of the great difficulty of breaking away from long-established soft-copper precedent and the somewhat greater difficulty of securing medium wire from manufacturers in comparatively small amounts, many companies are now, and in some cases have been for years, using the medium copper. This can be strung to sags which cause relatively no danger of swinging together, and with these sags will endure all ice and wind storms to be expected without such elongation as will seriously reduce conductor clearances from ground or other conductors beneath, since the yield point of medium copper is more than double that of soft copper when new. These companies have found no difficulty with medium copper in the making of joints, in most cases using sleeves and connectors with entire success, although in some cases making Western Union splices, which by their experience and by Bureau of Standards tests are shown, even where made with a blow-torch, not to reduce the strength of the conductor to an important degree.

At present some of the manufacturers do not keep this grade in stock, owing to the somewhat scattered and uncertain demand. Most, if not all, manufacturers will supply it on order at no additional cost, and several of them have stated it as their opinion that no soft copper should be used in the smaller sizes or for long spans in any size.

2. *Minimum sizes.*—The advantages in using the smallest allowable sizes of copper are frequently not so great as appear from the initial saving in copper over conductors of larger size. In regions where the load-factor is low or the connected load small, a larger size of conductor may of course not be warranted by the greater assurance of continuity of service, the ability to care for load increases, the better voltage regu-

lation, and the reduced maintenance charges. It may be seen, however, that such regions as really call for the smallest allowable conductors will usually be sparsely settled ones where grades A, B, and C construction are not required by this code.

Aluminum without reinforcement in small sizes is so light and its yield point so low that span lengths in ordinary use require sags so great as to cause constant danger of wires swinging together.

Even with steel reinforcement, aluminum is much lighter than equal sizes of copper and for the same sags would blow about more. As conductor sizes increase, a point is reached where for shorter spans the use of aluminum is feasible without undue hazards. The smallest size without reinforcement which has appeared safe for ordinary use is No. 1.

4. *Sags and tensions.*—Although the conductors in the spans between poles may be required to conform to several grades of construction, the sags recommended in Appendix A have been so selected as to provide a tension within proper limits, and sags fairly uniform, for all sizes of wires in spans where grades A, B, C, or N construction are likely to occur simultaneously. The liability of accidental contact due to swinging together in the span is therefore practically eliminated.

These sags have been derived from careful consideration of operating experience in maintaining service and providing safety, together with a study of the observed mechanical characteristics of conductor materials under operating and test conditions. The sag tables recognize the fact that requirements of construction practice make it necessary that sags in adjacent spans of different lengths (at least up to 150 feet) should be such as to provide approximately equal stresses in the conductor in the different spans at the time of stringing. The given sags also conform reasonably with the requirement frequently met in cities and specified in many franchises that the sags of all conductors of a span should be about the same, regardless of size, in order to eliminate a ragged appearance of the pole line and to prevent any reduction of clearance by having conductors at a higher level sag more than those below.

This provision for equal sags in all conductors on any one pole line is made only for spans of moderate length up to about 150 feet. It is in such spans that distributing lines of various sizes, and frequently a large number of wires, are usually found, and where the uniformity of sag is important from the standpoints of both clearance and appearance. Longer spans are more often confined to transmission or trunk lines on which wires of only one size are usually carried, and the sag best adapted to that particular size is then employed without the attending complications imposed by the presence of other conductors.

Large conductors may theoretically be strung to a less sag than smaller ones without exceeding their elastic limit when loaded. In practice, however, the tendency in general city construction is to use larger sags than are employed for the smaller wires, and the results of a large number of measurements made by the bureau indicate that, in general, the sags in heavy conductors, particularly in the shorter spans, are considerably in excess of those specified in the sag tables of these rules. There are several reasons for this: (1) Railway feeders and other heavy conductors if strung to small sags would impose undue stress on poles and fastenings particularly at angles, dead ends, and other points of unbalanced tension; (2) it is difficult to pull heavy conductors up to small sags with the apparatus usually employed in line construction; (3) heavy conductors do not swing in the wind as readily as do light ones, and the need for small sag is therefore not so great.

It may also be added that where heavy feeders are run on the same poles with other conductors they usually occupy the lower cross arm, where an excessive sag will not reduce but rather increase the clearance to other wires. A comparison of the sag values obtained by measurement in 15 cities situated in the heavy loading district with the curve of sag values recommended by these rules for corresponding span lengths is shown in Figure 17 for soft copper larger than No. 1 A. W. G. The numerals at the circles indicate the number of cities represented.

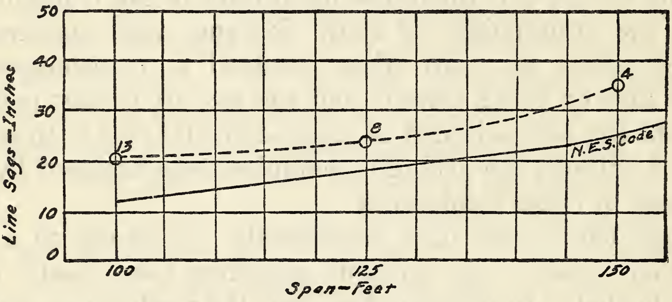

Fig. 17.—*Pole line sags for grades A, B, and C, heavy loading districts, No. 0, 00, 000, and 0000 A. W. G., triple-braid weatherproof soft copper wires*

Numerals at circles indicate number of cities represented.

In contrast to the practice regarding sags in heavy conductors, investigation shows that, except in short spans, it has frequently, though by no means generally, been the practice to string small conductors to sags somewhat less than those specified in these rules. This is particularly true in moderately long spans where the choice lies between the tight wires (in which case the greater stress under the heavy loading may cause excessive elongation or breakage) and wires strung initially loose, which greatly increases the chance of short-circuiting during severe windstorms. It is

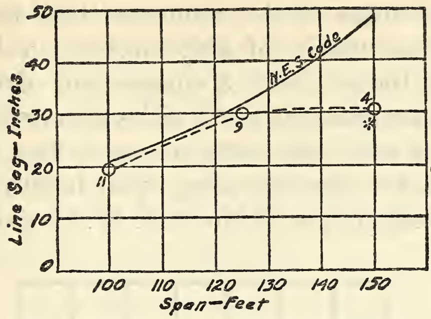

FIG. 18.—*Pole line sags for grade C, heavy loading district, No. 6 T. B. W. P. soft copper wire*

Numerals at circles indicate number of cities represented. *Illogical, but indicates that the accepted small pin spacings have made these sags necessary to prevent conductors swinging together. Such small sags, of course, require occasional slack pulling. Demonstrates the inadvisability of using No. 6 soft copper on 150-foot spans.

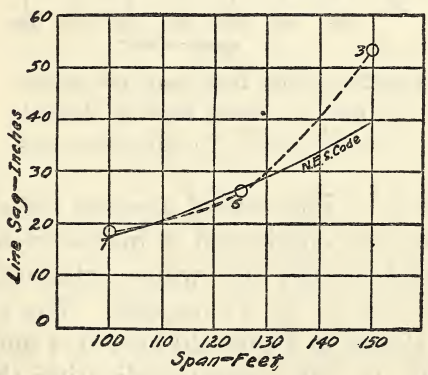

FIG. 19.—*Pole line sags for grades B and C, heavy loading district, No. 4 T. B. W. P. soft copper wire*

Numerals at circles indicate number of cities represented.

to escape both horns of this dilemma that the use of small conductors, particularly of soft copper, in long spans is discouraged in these rules. A comparison of the sag values obtained by measurement in 15 cities situated in the heavy loading district with the curve of sag values recommended by these rules for corresponding span lengths is shown in Figure 18 for soft copper of No. 6 A. W. G. and in Figure 19

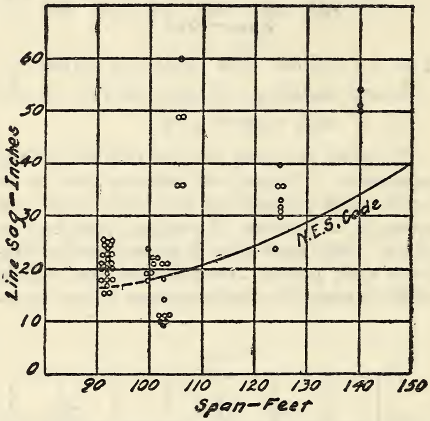

FIG. 20.—*Pole line sags for grades B and C, heavy loading district, No. 4 T. B. W. P. soft copper wire*

for No. 4 A. W. G. The ease of meeting the sag rules when the smaller sizes are eliminated is indicated by the experience of a typical eastern city whose minimum size of line conductor is No. 4 A. W. G. copper. The sag values, as measured, are shown in Figure 20 for No. 4 and in Figure 21 for No. 0 A. W. G. soft copper, indicating that in general the existing sags are much greater than the values recommended in these rules.

Conductors of hard and medium-drawn copper have mechanical characteristics which are much more satisfactory for line use than those of soft copper. In general, conductors of the former materials may be safely subjected to mechanical tensions up to 50 per cent of their ultimate strength or slightly more, since that will not appreciably exceed the yield point (or elastic limit) and so permanently elongate the conductor and increase the sag.

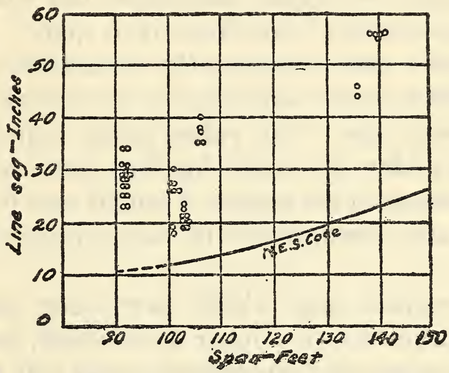

FIG. 21.—*Pole line sags for grades B and C, heavy loading district, No. 0 T. B. W. P. soft copper wire*

The normal sags recommended for hard and medium copper in the tables are such that the tension in the conductors, under the conditions of adverse loading, exceeds one-half the ultimate strength in but a few isolated cases of small conductors. This discrepancy has been recognized, and the somewhat insufficient sags of small conductors are permitted only on the basis of commercial necessity and present span-length and pin-spacing practice. Such a discrepancy is not recommended, nor is it considered good practice; as far as possible it should be obviated by eliminating small conductors from supply circuits. An effort to adjust the tensions in the smallest conductors to be not more than 50 per cent of the ultimate strength, when subjected to full load, would, however, result in such sags (normally or under load) that the total hazards from supply lines would be increased, due to the resulting frequent swinging together of conductors, unless much wider pin spacings than those at present used are introduced.

Iron and steel wires are not usually used for supply lines in the same spans as copper conductors, nor will there often be more than one size of wire in a given span. The sags for such conductors are consequently tabulated only in appendix B, without any adjustments for equalizing sags of wires of different size. The values given represent a maximum tension under the worst loading condition of 0.50 of the ultimate strength for grades A and B and 0.60 for grade C, and they are consequently to be regarded as minimum values.

Even the normal sags which have been permitted for hard and medium drawn copper and which, as noted, are so small for the smaller conductors as to call for excessive stresses under adverse loading conditions, are such that for the longer permissible span lengths the pin spacings should preferably be increased for the smaller conductors over those often used in present practice and permitted as minimum by rule 235, A.

No. 8 is particularly dangerous in long spans because, presenting so large a surface per unit of weight, it is liable to be blown about by the wind. Where trees are present and liberal trimming is not allowed, excessive sags are liable to cause grounding of wires or even their abrasion and breaking. In the matter of allowable span lengths it is evident that the variation of the sag for any particular span length and size of conductor due to change of temperature or loading of ice and wind is important, because clearances as specified in section 23 are wholly dependent for their adequacy on their maintenance under all weather conditions without substantial reduction.

Where 2-foot clearances are permitted for spans up to 100 or 150 feet, with very small increases by rule 233, B, for longer spans, these are necessarily based on a very moderate allowance for variation in conductor sag with increased temperature and with ice accumulations. The No. 8 hard or medium drawn conductor in 150-foot spans has a sag variation of nearly 2 feet between normal sag and loaded sag, and if crossing over or carried above a large conductor (say, No. 1) having only 3 or 4 inches variation of sag, a dangerous reduction of clearance would result, especially were the wind blowing across the lower conductor.

It will be found that if for any reason an exception to the rule is made in any case to permit a span longer than allowed by the table for the size of conductor concerned, the conductor separation will, by rule 235, A, 2 (*a*) (2) become excessive and usually prohibitive.

5. *Splices and taps.*—Tests on splices of all sorts in all kinds of wire have indicated that, in general, the splice is weaker than the conductor itself. This is particularly true in hard or medium hard-drawn wire and in the splices ordinarily made by workmen, as the wire is very often seriously weakened at that point. The presence of splices should, therefore, be avoided at crossings. Taps on hard-drawn wire have a weakening effect on the wire and should also be avoided in the crossing span. Splices should be kept out of adjoining spans as far as possible. This can not always be accomplished, so in special cases the splice is permitted in the adjoining span if arranged so that a failure at this point would not result in the broken wire swinging back into contact with a wire paralleling the railroad track.

G. Supply cables.

1. *Specially installed supply cables.*—The use of cabled supply conductors on joint poles with communication wires is very often a good solution of a difficult supply problem, especially where the tree conditions are very bad and where it is not desired to go to the expense of underground construction. Supply conductors constructed as cables should, however, be properly protected, preferably by means of a lead sheath to eliminate moisture and an armor to protect the lead sheath from abrasion and injury. On account of the higher voltages, the hazards occasioned by supply conductors in cables are, in general, greater than by communication conductors similarly installed, and they should therefore be protected more thoroughly.

When a supply cable is inclosed in a permanently grounded metal sheath, the hazards are largely eliminated and the details of construction are greatly simplified. It is preferable that such supply cables be installed low down on the supporting structure in order to reduce the resulting stresses as far as possible, still providing, however, the proper clearances at crossings and maintaining relative levels. This would result in minimum construction costs.

(*a*) MESSENGERS.

The installation of messengers supporting supply cables should receive the same careful consideration as is given to the installation of communication cable messengers.

(*b*) GROUNDING OF CABLE SHEATH AND MESSENGER.

In order that the hazards of a supply cable may be minimized, it is necessary that the cable be properly grounded. The most satisfactory methods for doing this may vary in different localities, but it has been considered sufficient to bond the cable to the messenger at not less than two points between splices and ground the messenger at least every 800 feet.

(*c*) CABLE SPLICES.

The splice is generally considered the weakest point electrically in the supply cable, and therefore particular care should be exercised in making the joint. It is not the purpose of this discussion to give detailed specifications for making splices in cables, as there is a great deal of literature covering the subject at the present time. Where properly made, the splice may have an insulating value superior to the remainder of the cable. There are certain difficulties experienced at splices in cables which have the lead sheath protected by armor on account of the necessary bulge of the splice; but methods have been found to overcome these difficulties and protect the lead sheath at this point. The bonding of the cable to the messenger must be carefully done to prevent damage to the cable and still give the necessary carrying capacity.

(*d*) CABLE INSULATION.

As the supply cable is generally covered with a metallic sheath or armor, a superficial inspection of the exterior of the cable is not sufficient to determine its insulating strength. This is generally done by applying a test voltage equal to twice the operating voltage for five minutes. This test has been considered sufficient to indicate a safe operating factor of safety and take care of voltage increases occasioned by surges or other disturbances. It is certainly for the benefit of the supply utility making use of the cable that the test voltage be sufficiently high to insure against interruptions in service after the installation of the cable.

2. *Other supply cables.*—Unless supply cables have metal sheaths properly grounded, they really constitute a greater hazard to linemen than do open supply wires of the same voltage on account of their innocent appearance. They should, therefore, comply with the requirements of the proper grade of construction as determined by the voltage of the cable, just as if open wires were used.

H. Open communication conductors.—It is considered that the sizes and sags specified for grade D construction give a reasonable degree of security. It was, therefore, decided that if these same sizes and sags were realized for those cases in which grade C is necessary for communication wires the strength would be sufficient for the degree of hazard involved.

K. Short-span crossing construction.—There are certain special construction specifications for crossings sometimes employed in practice which have for their purpose the reduction of the hazards involved and of the costs of construction and of the possible complications where a different grade of construction is required at the crossing. One of the most common of these special crossings is that employing a very short crossing span and making use of supporting structures at the crossing high enough to prevent the conductors, in case of accidental breakage, from coming in contact with the line crossed. This feature eliminates the minimum requirements for the conductors themselves, but the transverse and longitudinal strengths of the supporting structures are not affected, and, in addition, proper grounded guards must be provided to prevent, in case of breakage, the much longer conductors in the spans adjacent to the crossing span from coming in contact with the conductors crossed over. It is questionable, however, even with this construction, whether any particular reduction in cost is obtained in view of the necessity for higher structures and the possible additional supporting structure which may be required. (See figs. 22 and 23.)

L. Cradles at supply-line crossings.—Another special type of construction sometimes employed at crossings is that making use of cradles or hammocks placed between the supply conductors and communication conductors constituting the crossing and so designed as to catch and ground a supply conductor which may break at any point between

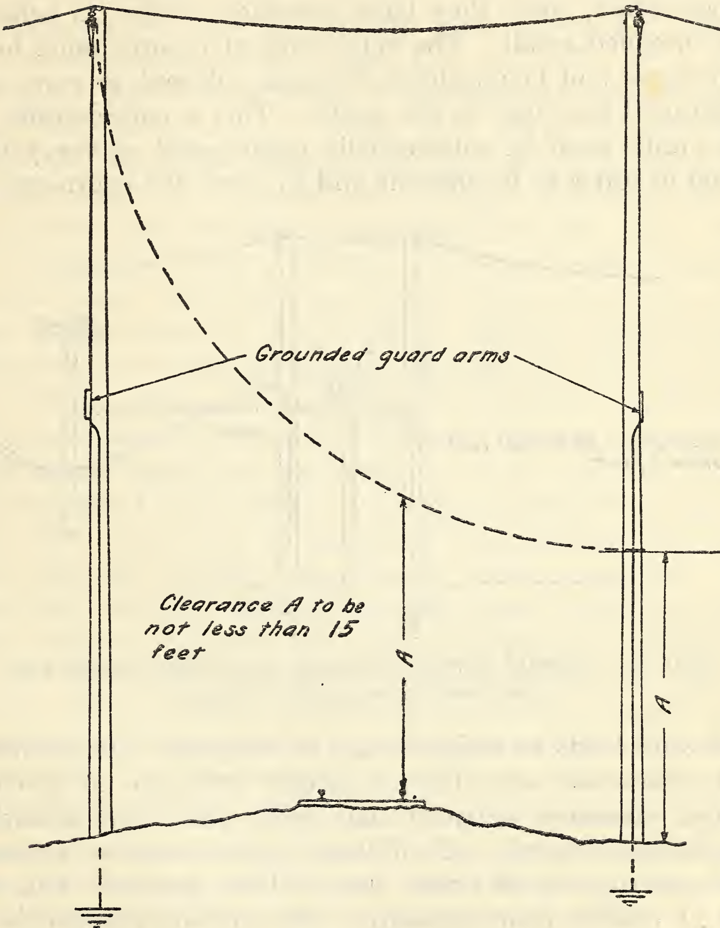

FIG. 22.—*Special short-span crossing construction, supply lines over railways*

the supporting structures at the crossing. It is very questionable whether the hazards involved are reduced by such construction, since they have sometimes failed to achieve the intended result. The supporting structures must have transverse and longitudinal strength sufficient to carry the additional load due to the cradle. This is considerable, as the cradle must be substantially constructed of heavy material in order to be efficient and to carry the enormous ice

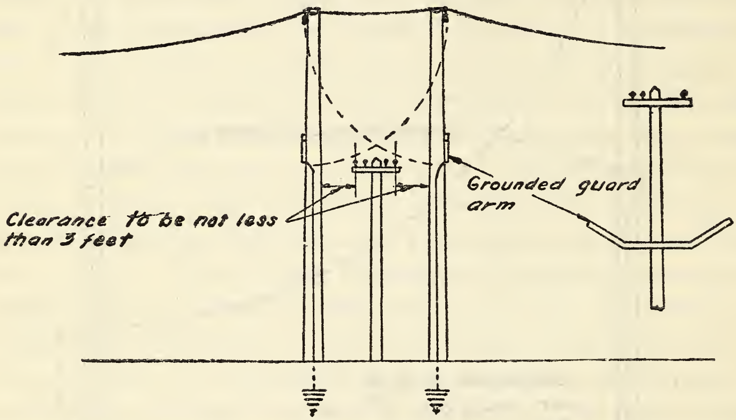

FIG. 23.—*Special short-span crossing construction, supply circuits over communication circuits*

and wind loads to which it may be subjected. In addition, the structures must have a height sufficient to provide proper clearance between the cradle and communication conductors crossed. All of these factors together increase the cost to such an extent that utilities generally find the use of cradles poor economy. The present practice is to avoid them altogether. A lesser investment devoted to strengthening the crossing span itself will generally give much more satisfactory results.

262. Grades D and E Construction.

An examination some years ago of existing construction of communication lines at crossings over railroads in regions of heavy loading showed that rule 262 calls for a considerably higher standard of construction at railroad crossings than had been usual in the past. Data were collected in New York, New Jersey, and Connecticut showing the construction at a number of crossings over railroads of open-wire telephone lines ranging from 30 to 60 wires. This is in the district of heavy loading. The ages of these crossings varied from 1 to 31 years, and only 10 per cent of them met the requirements of the American Railway Association's specifications contained in their Circular No. 1497, in force at the time. Most of the crossings were built prior to the time those specifications were put into force. Not one of the crossings would meet the requirements of the National Electrical Safety Code of 1916. In the data collected the records show that there were no failures of structures or guys and that but one crossing caused any trouble whatever. In this case, because of right-of-way difficulties, a longer crossing span than is desirable had been constructed, resulting in several wire breaks during cold weather within the past 20 years. This particular accident indicates the necessity for a stronger grade of construction with greater sags where communication lines conflict with supply lines, as the sole damage occasioned by the accident was the result of contact between the broken telephone wire and an adjacent power wire. The present American Railway Association's specifications are substantially the same as required by this code.

Efforts have been made repeatedly to secure data on actual failures of communication lines at crossings. Outside of the one case described above the replies to such inquiries have indicated that the only crossings which have given trouble are those which do not conform to the requirements of any recognized rules and should not be tolerated under any conditions.

There is one basic difference in the hazards due, respectively, to supply and communication lines. Supply lines present a mechanical hazard due to falling wires and poles, as well as an electrical hazard due to high voltage; hence fairly large wire sizes are specified as minimums to prevent supply wires from breaking except under very unusual conditions. On the other hand, with communication lines where supply lines do not conflict, only the mechanical hazard exists; namely, that of poles or wires falling on and interfering with railroad dispatch wires, or wires sagging so as to intercept men riding on top of the cars. Since the broken wires will usually clear the railroad dispatch wires without seriously injuring them, the crossing wires are permitted to be strung so that under the worst (unusual) conditions the wires may break and relieve the poles rather than pull them down.

A. Poles.

3. *Strength requirements for poles where guying is required, but can only be installed at a distance.*—Although this is not a desirable way of guying a crossing pole, it is considered as a reasonable alternative where it is impracticable to guy the crossing pole, since some of the rigidity given thereby to the guyed structure will be transmitted to the crossing poles through the head guy, the amount transmitted depending greatly on the tautness of this head guy and the rigidity of the guyed structure.

4. *Pole locations at crossings.*—It is very desirable that the crossing span shall be in line with the adjacent spans so as to make it comparatively easy to determine the resultant loads on the poles and also to compensate for them by proper guying. Keeping the line free from overhanging trees (especially dead and partly decayed trees) will, of

course, help eliminate the possibility of wires breaking in a span adjacent to the crossing, and thereby putting a big stress in the head guys.

8. *Poles located at crossings over spur tracks.*—Lines which parallel railroads for great distances make a grade E crossing each time they cross a spur track leading to a manufacturing plant or to a warehouse, for instance. There are consequently an extremely large number of such crossings. The installation of side or transverse guys under these conditions would, in general, produce a very complicated system of overhead guys and stubs. The necessity for such guys is but very little greater than elsewhere along the parallel line which conflicts with the tracks practically throughout its length. The only additional hazard at the crossing over the remainder of the line is the possibility of a wire falling. The wire sizes, however, are those required for grade E crossings under other conditions.

9. *Height of poles adjacent to crossing poles.*—This rule is intended to prevent an excessive upward pull or downward thrust on the pins or insulators of the crossing supports, and thereby if pulling up, either pulling the insulator off the pin or the pin out of the arm, and if pulling down, stripping the petticoat off an insulator where a side tie is used, or even pulling the cross arm from its fastening. The dimension to be measured is shown in Figure 24.

B. Pole settings.—A number of tables specifying the depths to which different sized poles should be set have been devised and adopted by a large number of operating utilities. These tables are substantially identical, the differences in depths specified varying only from 6 inches for short poles to 2 feet for extra long poles. However, as the nature of the soil or its ability to support a pole varies greatly, occasionally even within a few spans of line, it is unsatisfactory to specify any exact figures to follow in every

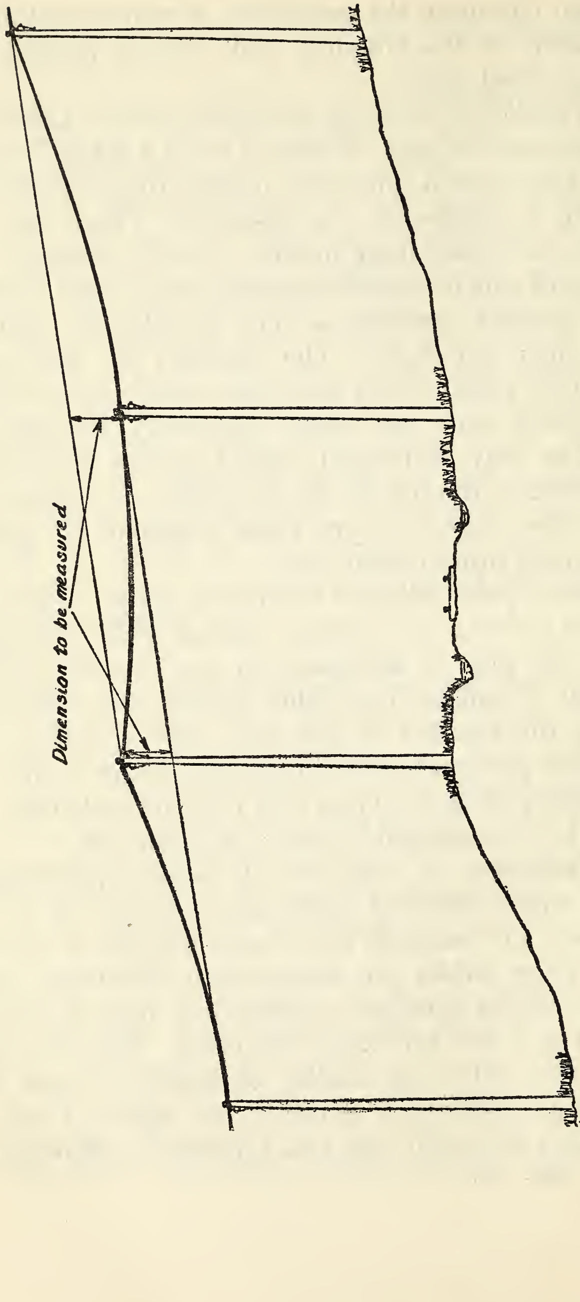

FIG. 24.—*Grading or vertical displacement of poles in crossing span*

case. It was considerd best, therefore, to specify merely the one basic condition, namely, that the application of the load will not loosen the pole in its setting. This naturally leaves a great deal to the discretion of the foreman or man in charge of the construction.

Poles set in dry soil require a great deal more care than those set in damp soil. The tamped soil in the former case when subjected to moisture may settle to such an extent as to materially reduce the effective depth of the setting. Sand requires special consideration and should be avoided where possible. The use of concrete is sometimes a satisfactory solution of the difficulty. Marshy soil offers some of the most difficult problems to be found in the setting of poles. Cribbing or very long piles may be used, together with a proper application of guys. Exposure to washout, in river or creek beds, should be guarded against. Future grade changes may seriously reduce the depth of the pole setting and should receive attention. Poles set on sloping banks are subjected to the possible sliding of the soil, especially on new cuts or fills. The action of different soils on the butts of poles is fairly well understood at this time, but it is rarely given any attention by the foreman, as he seldom places an extra long pole where the rotting effect will be greatest. All of these factors together require something more than the application of a table of pole-setting depths in order that a line may be constructed in the best manner possible. The table given in Appendix F specifies pole-setting depths for construction under average conditions.

C. Guys.

2. *Where used.*—The maximum of two wires permitted without head guys for grade D is not increased for grade E, as this limit is not based on the actual strength of the pole.

The majority of grade D crossings are those made by communication lines, both railroad signal lines and telegraph lines, which parallel the tracks on one or both sides throughout the length of the railroad. Where, on account of the contour of the land or natural obstructions, it is necessary to cross the tracks, such a crossing is generally made at an angle of less than 45° with the track. It is a rather difficult matter under this type of construction to install a side guy on the inside of the angle between the crossing pole and the track, at least in the great majority of cases. The installation of an overhead guy on account of the necessary clearances and additional pole required would probably produce a greater hazard than if the guy were omitted.

5. *Location of guy anchors.*—It will practically always be possible to install head guys at angles of not more than 45° with the horizontal, and since the effective strength of a guy decreases very rapidly for bigger angles, this angle of 45° has been specified as a desirable limit. With side guys, cases will often arise where a good angle giving a good effective guy strength will be utterly unobtainable, and therefore a ground angle of as much as 71° is permitted. However, for angles greater than 71° so much of the guy strength is lost that it will usually pay to use other methods of supporting the pole, such as braces or long leads to stubs.

D. Cross arms.—The chief reason for requiring double cross arms on crossing poles is to eliminate as far as possible the slipping of conductors through their tie wires, and thereby dangerously increasing the sag in the crossing span. The frequency of accidents wherein men on the tops of freight cars are pulled off by low wires, especially in bad weather, is such as to make this matter very important.

E. Brackets and racks.—A former rule entirely prohibited wood brackets, but it has been decided that they may be used with entire safety if used in duplicate, so as to provide two tie points for each conductor. It is important to securely spike the brackets to the poles. Too short nails, which merely enter the sapwood, have very little holding power.

F. Pins.—The permissible maximum length of shank for both wood and steel pins has been omitted to permit the use of some sizes of pins which are in fairly common use and which have been found to give ample strength but which would not be permitted with the limits set in a previous edition.

H. Attachment of conductor to insulator.—The sentence requiring that conductors be securely tied to their insulators has been added for the purpose of eliminating, as far as possible, the chances of conductors slipping through the tie wires and thereby dangerously increasing the sags in the crossing span. With small bare conductors it is often impossible to prevent slipping with a single standard tie, and, therefore, double cross arms, pins, and insulators are required.

I. Conductors.—The minimum size for steel-reinforced aluminum has been omitted because in the various surveys made by the bureau no such wire has been found in use for communication purposes. Its use is, however, not prohibited.

The minimum sizes permitted for grade E are, in general, a little smaller than those permitted for grade D. However, it was considered unsafe to permit a copper wire as small as No. 12 A. W. G. over any railway in regions of heavy loading, and the minimum size for such places has, therefore, been placed at No. 10.

The use of paired conductors without messenger support over railroads is decidedly undesirable and should be discouraged and avoided wherever possible. However, it is considered safe practice to use such wire without messenger support on spans not exceeding 100 feet for grade D and 125 feet for grade E.

J. Messengers.—The rule in a previous edition, which grouped the permissible sizes of cable according to the number of pairs contained, was found impracticable because there are now so many types of cables having the same number of pairs but having different weights per foot. The latter should, of course, be the controlling factor in determining the permissible size of messenger, and, therefore, the present rule states the limiting weights of cable permitted with the three strengths of galvanized-steel messenger cable most generally used.

Since the tension in the messenger controls the permissible sag, the limiting safe tensions for the three strengths of messenger strand most generally used have been listed.

K. Inspection.—This rule at first glance appears to be somewhat stringent. It is not intended, however, to require an annual replacement inspection of the crossings, but it is desirable that the crossings be well maintained and that defects which would weaken the crossing be promptly corrected. Inspection by a properly qualified employee, such as a section lineman, for the purpose of maintaining the crossing construction in a safe condition will be considered as meeting the requirements of this rule. The various rules of the code will naturally determine this safe condition. A guy may have slipped or become broken or the pole may become splintered and seriously weakened by accident. Where an important crossing is concerned, the hazards may be greatly increased by such an occurrence, and systematic inspection is therefore very important.

263. Grade N Construction.

A. Poles and towers.—With a pole the hazard always exists of its falling over and injuring some one, but service requirements will in most cases necessitate the use of poles large enough to prevent this. However, the general requirements of this code, not relating particularly to strength, should be complied with in all cases.

Especially with poles on which transformers or other equipment are to be installed, it is necessary that they have sufficient initial strength to support the maximum load that might be installed on them, the more so because of the prevalent tendency to avoid added cost of construction by making existing construction serve for loads larger than those planned when the construction was first installed.

D. Supply-line conductors.

1. *Material.*—In choosing the material for supply conductors consideration should always be given to the question of excessive corrosion of that material in the particular locality. Iron or steel wires near a seashore where considerable moist salt air is brought in contact with them will often corrode so rapidly as to become dangerous if only ordinary maintenance is given them. At crossings over railroads even copper wires will sometimes corrode dangerously if they are very small to begin with. Iron or steel conductors should never be used unless well galvanized. It is recommended that the practice of pulling conductors along the ground from stationary pay-out reels be avoided, as this practice tends to remove the galvanizing and materially to shorten the effective life of the conductor.

2. *Size.*—Soft copper will stretch so much under its own load (and more so when loaded with ice) that it is decidedly dangerous to use it in sizes smaller than No. 6 in spans of normal length. Even with larger sizes the stretch is such as to make necessary the pulling up of slack after the wires have been subjected to a large ice and wind load. See also rule 261, F, and its discussion.

Hard or medium drawn copper is nearly twice as strong as soft copper and stretches very little. A somewhat smaller size is therefore permissible.

Steel wire in the smaller sizes has about the same strength as hard-drawn copper, but since it will generally corrode faster a slightly larger wire is required as a minimum. No. 9 steel is more than a size large than No. 8 copper. It should be noted that the steel-wire gauge is used in designating sizes of iron and steel wire and the American wire gauge (or Brown & Sharpe gauge) for copper.

Aluminum in small sizes without reinforcement is so light and its yield point so low that span lengths in ordinary use require sags so great as to cause constant danger of swinging together. As conductor sizes increase, a point is reached where for the shorter spans the use of aluminum is feasible without undue hazard. The smallest size which has appeared safe for ordinary use is No. 1. The sag tables in Appendix B indicate limiting span lengths for the smaller sizes of grades A, B, and C, and the latter may well be followed for grade N.

Even with steel reinforcement aluminum is much lighter than equal sizes of copper and for the same sags would blow about more.

E. Supply services.—Service leads of considerably smaller size than line wires of the same voltage are permitted because they are usually strung to much greater sags in order to relieve the poles of unbalanced side loads and reduce the pull on buildings to which they are attached. However, on account of their small size and the nature of the attachment at the building, such leads are frequently torn down in storms and many utilities find it advisable to use larger sizes generally, except possibly in outlying districts and where the load to be supplied is quite small. Where the service crosses a trolley contact conductor the necessity for larger sizes is apparent.

It is considered that for voltages of more than 750 supply service leads should for all purposes be considered as line wires and be built accordingly.

Cabled service leads are in many cases preferable to individual wires, but care should be taken at the attachments that the wires are properly separated and fastened.

H. Cradles at supply-line crossings.—See discussion of rule 261, L.

Sec. 27. LINE INSULATORS

271. Material and Marking.

Where grades A and B construction are required for supply lines, on account of the hazards represented by the voltages concerned, it has been considered necessary to specify minimum requirements for several of the characteristics of the insulators supporting the conductors. At the present time, on account of the trend toward higher-voltage transmission lines, continual changes are being made in the design and methods of manufacture of insulators in order to make them stronger mechanically and electrically. These changes are necessary on account of certain factors which were not formerly completely understood. Porcelain is being almost universally used for insulator purposes, particularly in the higher-voltage types, as it has been found to have mechanical properties far superior to any other insulator material known at the present time. Its electrical properties are also excellent, providing that the porcelain is properly manufactured. For purposes of future investigation it is highly important that each insulator have a distinguishing mark. This is easily accomplished where suspension or strain-type insulators are concerned, as the metallic parts can be utilized for this purpose. However, pin-type insulators present some difficulties in this connection, and care should be exercised to see that such markings do not reduce the strength of the insulator.

272. Electrical Strength of Insulators in Strain Position.

Strain insulators are necessary at dead-end structures and are sometimes employed at crossings as well. The art of designing strain insulators has advanced to such a point that they are extremely reliable. Where they are employed they should not offer a reduced electrical strength which might make a weak point in the line.

273. Ratio of Flash-Over to Puncture Voltage.

The value specified as the minimum requirement for the ratio may appear to be somewhat high. In fact, very serious consideration was given to this matter, and 50 per cent was considered as a substitute. However, answers to a questionnaire sent out to a large number of engineers failed to include a report of actual failures of insulators which had a ratio of flash over to puncture voltage less than the chosen value. In fact, one utility specifies a value very close to 75 per cent. It is known that aging has a considerable effect on many of the characteristics of insulators, but there does not seem to be sufficient information available at this time to warrant reducing the value on that account.

274. Test Voltages.

This rule gives the minimum values for dry flash-over test of the insulators used on lines of various voltages. The committee has collected data regarding current practice in the selection of insulators for line use, and the accompanying table gives current average American practice in this regard.

TABLE 1.—*Current average American practice test, dry flash-over voltages*

[The range of flash-over voltages given below is based on the following line conditions: Intermittent rains, heavy lightning, extensive system, on metal pins, grounded neutral system, in open country.]

Nominal line voltage	American practice—Dry flash-over voltages	
	From—	To—
22,000	90, 000	115, 000
33,000	110, 000	135, 000
44,000	135, 000	155, 000
55,000	165, 000	180, 000
66,000	185, 000	200, 000
88,000	230, 000	280, 000
110,000	340, 000	380, 000
132,000	420, 000	460, 000

275. Factory Tests.

There is not entire agreement among engineers and manufacturers as to the proper tests which each insulator should receive at the factory. On this account the requirements of the rule are not as explicit as they might otherwise be. The values for test voltages given in Table 33 have been found to be more than met in actual practice. On account of various atmospheric and other conditions certain utilities have found it necessary to employ insulators which are rated at as much as twice the values given in the table. This may occur where salt fogs are prevalent or where the air is polluted with dust fumes or other matter, as in the neighborhood of cement mills or smelters.

At the present time the 60-cycle test is ordinarily employed at the factory on all insulators. Some specifications call for the application of the testing voltage for five minutes, but as nearly all of the weak insulators are located in the first minute of the test it has been found that three minutes is a satisfactory minimum period of time. However, the high-frequency impact test is coming into general use for some types of insulators, and on this account the use of the 60-cycle test is not made mandatory. The high-frequency test has been found to be very valuable for eliminating insulators which have a porous or open space in the porcelain and does this, perhaps, more readily than the 60-cycle test.

In addition to the voltage test, there are other mechanical tests which are often included in the specifications. Perhaps the most important of these are the strength, porosity, and temperature tests. The first of these is, of course, necessary to determine the tensile strength of the insulators and the condition of the cement which may be employed to join the various parts of the insulator together. The porosity test is extremely valuable, as this characteristic results in failures after the insulator has aged. This test is generally, therefore, very severe in that the colored liquid which is employed is applied to the insulators under pressure for a considerable period of time.

Experience has demonstrated that insulators often fail on account of the variations in the atmospheric temperature which cause small cracks to appear in the porcelain and ultimately cause the failure of the insulator. For the purpose of predetermining the ability of the insulator to withstand this effect, a temperature-cycle test is sometimes specified. In this connection it may be well to call attention to the installation of pin-type insulators. Many failures have been found to result where the insulator has been screwed down too tightly on the pin, so that expansion and contraction have finally split the insulator. This is especially true where thimbles of soft metal or some other flexible mounting has not been employed with metal pins.

277. Protection Against Arcing.

This rule, as stated, permits a great deal of latitude in insulator installations and is inserted merely to insist on as great protection as is available. This matter has caused a great deal of experiment. Arcing horns as a means of protection seem to have a real value. However, a number of utilities report cases of failure, where conductors have burnt down, which are traceable directly to the use of arcing horns. On account of the distribution of potential within the insulator string, it is possible for the arc to strike into the string under some arrangements of the arcing horns.

Another means of protection utilizes static shields, such as have been developed by radio engineers. This, however, has its faults, as it practically short-circuits one of the units in the insulator string under certain conditions. However, it materially reduces the strain on the insulator nearest the line.

Rule 278 describes construction which will fully meet the requirements of this rule. While such construction is recommended, it is not to be considered mandatory.

Sec. 28. MISCELLANEOUS REQUIREMENTS FOR OVERHEAD LINES

280. Supporting Structures.

A. Poles and towers.

1. *Rubbish.*—The accumulation of brush, grass, and rubbish around the bottom of a pole or tower presents several dangers. It interferes with proper inspection, and with wooden structures it accelerates decay and increases the fire hazard to the structure. It is advisable that seasonal inspections be made, especially on important high-voltage lines installed on wooden supporting structures, particularly during those periods when fires are liable to occur.

2. *Guarding poles.*—At points of heavy traffic the strength of a pole not protected by a guard can be very appreciably reduced by repeated knocks from vehicles, and for this reason wherever such an occurrence is likely the poles should be provided with a traffic guard of some form. Concrete sleeves extending a few feet above and below the ground line, if properly designed and installed, make very effective wagon guards and add considerable strength to the pole. However, experience has indicated that in some cases such a sleeve or inclosure may actually promote decay, because it confines moisture in the pole. Steel or iron plates are also used for this purpose, but if they are too high or inclose more than half of the pole they may prove a menace to the men having occasion to climb the pole.

3. *Warning signs.*—Warning signs are often disregarded, but where they are used they should be of proper design.

Signs warning against trespass and calling attention to hazard are available in durable form to meet most ordinary requirements where metal poles or towers are concerned. On wood poles stenciled signs are the only ones that should be used; metal signs, either flat or curved, would be a decided hazard to linemen by cutting and tearing them or causing their spurs to slip. Small individual letters or figures of thin aluminum may be harmless. Such signs are only required on poles which can be readily climbed by unauthorized persons.

5. *Pole steps.*—All overhead supply circuits should be inaccessible to unauthorized persons, at least as far as it is possible to make them so. The best method for so isolating supply wires is that of making the climbing of the supporting structures difficult without the use of special means, such as ladders, spurs, or removable steps. Steps should not be installed nearer than 6.5 feet to the ground. The use of steps on the portion of the structure out of reach of the ground is very desirable under certain conditions. Metallic structures require steps in order that they may be easily climbed by authorized persons. Nonmetallic structures are easily injured by the use of spurs, and where this would be particularly objectionable—as, for instance, in urban territory—steps should be employed.

6. *Identification of poles.*—It is important that pole or tower structures should be readily identified by location, construction, or marking to minimize mistakes by employees working on them or reporting with regard to them.

7. *Obstructions.*—Obstructions, such as nails, bolts, tacks, or other metal pieces, may keep the lineman's spur from taking hold, thus causing the lineman to fall. Mail boxes, street signs, and traffic-direction signs, when obstructing the pole, may make very handy steps for the men climbing poles, but they constitute a serious hazard when so used, as they are usually insecurely attached.

C. Unusual conductor supports.—It is apparent that when conductors are attached to supports not used chiefly for this purpose, such as buildings or frame structures, conditions introducing a hazard are very likely to arise which were not foreseen by those making the attachment, and which, if foreseen, would have changed the method of attachment. For this reason it is usually undesirable to make such attachments, even where there may be no immediate hazard introduced by an attachment properly made and maintained. Tree attachments suffer displacement due to growth and swaying in the wind. Roof attachments are more subject to interference than attachments on poles and involve placing the wires where they are more easily accessible to unauthorized persons.

281. Tree Trimming.

The avoidance of contact of line conductors with trees is a difficult problem in many localities. Sometimes where large trees are present the poles are high enough to clear the trees without trimming, and sometimes considerable trimming is necessary. It is important to keep the wires clear by one method or another, to avoid grounding the conductor and carrying high voltages to points where they are hazardous, as by two wires touching the same branch. Trees which shed their bark, such as the eucalyptus, or trees which are extremely brittle, such as the poplar, should be avoided, if at all possible, or trimmed below the level of the supply wires, if permission may be secured. The use of properly designed tools for this purpose is particularly important. Tools designed for the use of orchardists or gardeners are very rarely safe or suitable for use in this connection, for the reason that metallic connections often are present between the cutting head and the operating handle. On this account they should be avoided, as workmen may be very seriously hurt or even killed by actual contact with high-voltage supply wires or by being thrown from a tall ladder or from the tree itself.

Trees are always a menace, particularly where they are taller than the supporting structure. Care should be taken to avoid them at crossings as far as possible.

282. Guying.

A. Where used.—A pole should have sufficient strength to support its load, and if it does not meet this need the necessary strength should be provided by other means. This applies not only to definite strength requirements in these rules, but to poles for which no transverse strength requirements are made. Storm guys for wood poles are accepted practice in most parts of the country. When it is necessary to give additional support to a pole by the use of a guy, the lead of the guy (horizontal distance from pole to attachment of guy and anchor) should, where practicable, not be less than two-thirds the height above ground of the attachment of the guy to the pole, and the anchorage to which the guy is attached should be capable of withstanding the load to which it will be subjected. Sometimes a head guy may well be carried back to the next pole in line.

In addition to the usual practice of installing guys at angles, corners, dead ends, etc., where the strains are due to the conductors, they should also be installed on structures or poles carrying very heavy transformers or other similar equipment, which would produce a serious top-heavy condition. The increased load caused by wind pressures on such equipment might cause failure to the structure which would otherwise be sufficiently strong to support the load due to wind action on the conductors alone. It is advisable that storm guys be installed on extremely heavily loaded lines as an additional precautionary measure, such guys to operate in all four directions.

Where the forces acting upon a pole are not normally balanced, as at angles in the line, the steady pull is likely to gradually displace the pole from the vertical position. This may not lessen its ability to carry its load but is objectionable from the standpoint of appearance and also because, by slightly lessening the length of span, it increases the sag of the wires and reduces the original clearances. In such cases it is desirable, therefore, to apply guys in such position as to have the stress in them balance the otherwise unbalanced tension in the wires. This is especially true at sharp corners and also at dead ends. In the latter case head guys are, of course, required. Where there is a change in the grade of construction, longitudinal strength of line supports is called for, and this can ordinarily only be supplied by the use of head guys.

Many cases of angles in the line and other instances of unbalanced load may involve considerable calculation to determine the strength of guy required. If in such a case the size of guy be estimated, a size should be selected which will put it on the safe side of the requirement.

B. Strength.—A wooden pole develops resistance to bending only as it is bent, and the deflection of the top of the pole is considerable before the fiber stress reaches the limiting value fixed by the rules. A very much smaller stretch of the guy will develop its maximum strength, especially as it is normally installed with initial tension. It is evident that the ultimate strength of both can not be utilized simultaneously. Consequently, when a guy is used it is required to be strong enough to carry the entire horizontal load. The same applies to flexible steel towers and to concrete poles.

D. Guy fastenings.—A guy of high strength can do considerable damage to a wood pole if no guy shim is used, especially if the pole is of soft wood. After the pole is once

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cut to any appreciable degree by a guy wire there is some likelihood of its snapping off at the cut under heavy pole loading.

Thimbles should be used on guys when attaching to anchor rods, as by so doing the point of application of the load is distributed in the wire.

E. Guy guards.—A guy wire is not only hard to see at night but also by day in stormy weather, and if it is in the path of pedestrians it can cause serious accidents which in

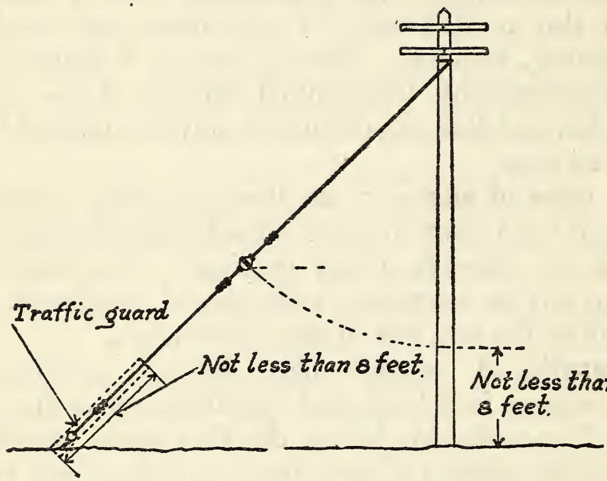

FIG. 25.—*Guard and insulator for guy*

most cases would be avoided by covering the guy with some conspicuous material, such as wooden molding painted white, or with white and black stripes. Such a guard also helps to protect the guy from mechanical injury. (See fig. 25.)

F. Insulating guys from metal poles.—Frequently anchors for guys are subject to severe electrolysis conditions where d. c. railways are in the immediate vicinity and the anchor rods practically destroyed. This may be prevented by using suitable insulating blocking between a guy wire and a metal pole, or by using strain insulators in such guys.

G. Anchor rods.—The anchor rod and anchorage are subject to much more rapid deterioration than the guy wire; hence they should be of sufficiently heavy material. In general, anchor rods are of such lengths that their full strength is developed by the anchorage only when installed in solid earth with not more than 12 inches of the rod projecting above ground.

When lining up the pull of an anchor guy installed in earth an error is frequently made, and when installed the anchor rod will have a sharp bend near the eye. This should not be permitted, as the rod has no holding power in the direction of the strain under such conditions and the guy would soon become slack.

Where anchor rods are held in the earth by means of wooden blocks or pole sections, sometimes called dead men, washers should be installed on the anchor rod of sufficient size to prevent the anchor pulling through the blocks when subjected to the strain for which it is intended. A washer not less than 4 inches square is recommended.

Anchor rods installed in rock are generally of a special type and are placed at right angles to the direction of the strain, thus securing greater effectiveness.

H. Grounding.—As explained under rule 283, the proper grounding of the guy is the only reliable precaution against life hazard at voltages exceeding 15,000 unless a high-voltage strain insulator is used. As it is not usual for workmen to work among live wires at this voltage, the objection to carrying the ground up the pole is minimized.

283. Guy Insulators.

The attachment of an uninsulated guy wire to a wooden pole has the effect of bringing the ground up the pole and reducing the length of the wood pole which is depended upon for resistance. A workman may come directly in contact with this guy and a live electrical conductor at the same time. Suitable insulators installed in the guy afford protection both to the workman on a pole and to the pedestrian below. Such insulators are not usually necessary in guys attached to metal poles where the whole structure is well grounded, except where near grounded railway circuits. (See rule 282, F.) With conductors all of less than 300 volts to ground sufficient hazard does not really exist to warrant the requirement of a guy insulator, but often the primary wires are installed subsequently, and since guy insulators would be required in that case it is evidently advisable to install them in all cases to avoid replacing a guy already installed. Where conductors are of more than 15,000 volts, guy insulators are not required because those now generally used can not be relied upon for such high voltages, and the only dependable alternative is the thorough grounding of the guys. Since the object of the guy insulator is twofold—namely, to protect the workman on the pole and the pedestrian on the street—it should be so placed, when possible, as to be out of reach both from the pole and from the ground. Furthermore, it should be placed so that if the guy breaks at the insulator the part attached to the pole will not come close enough to the ground to be within reach of passers-by. (See fig. 25.)

In many instances, especially where a guy passes over supply wires, it may require two or even more insulators to meet all of the above conditions.

A. Properties of guy insulators.—The guy insulator should generally be somewhat stronger than the guy in which it is used, because a guy or thimble may be used which will distribute the mechanical stresses in the insulator differently than that for which it was designed, and this might cause its failure. A type of insulator in which the two sections of the guy interlock in the event the insulator fails is generally preferable to a type in which the guy sections separate.

B. Use of guy insulators.—It has been held by some engineers that with the grade of construction required for supply lines there is little danger of supply wires breaking and falling on guys, and, therefore, insulators should not be required in guys passing under high-voltage wires. Others have held that the breaking of a guy wire is a rather unusual occurrence, and that, therefore, insulators need not be required for guys passing over supply wires. However, experience shows that both supply wires and guys of considerable strength do break at times, not only because of storms but also because of accident, and contacts sometimes occur due to sagging or tightening of wires, but by properly placing the insulators (two or more) the section of the guy which may become alive in any event can be isolated so as to be out of reach from the ground, whether the guy breaks or not. Although this may in some instances require a study of the possibilities in the way of failures, there should be no real difficulty in the practical elimination of all hazards from this source. (See fig. 26.)

The installation of insulators in guys so that they will be effective even if the guy sags down onto another one can be accomplished by using a little extra care in determining its exact location or by using an extra insulator, and also by fixing the points of attachment of two or more parallel guys.

Since grounding a guy is preferable to insulating it, no insulators are required in guys attached to grounded steel structures or grounded parts on wooden structures or if the guys from wood poles are consistently grounded.

284. Span-Wire Insulators.

When wood poles carry no conductors or attachments except a lamp or trolley suspension wire, a single insulator at the hanger may be sufficient, since the wood pole provides a long path to ground of high resistance. The public is endangered only by leakage through the pole to ground, and the workers in this case know the hazards of the devices to be worked on.

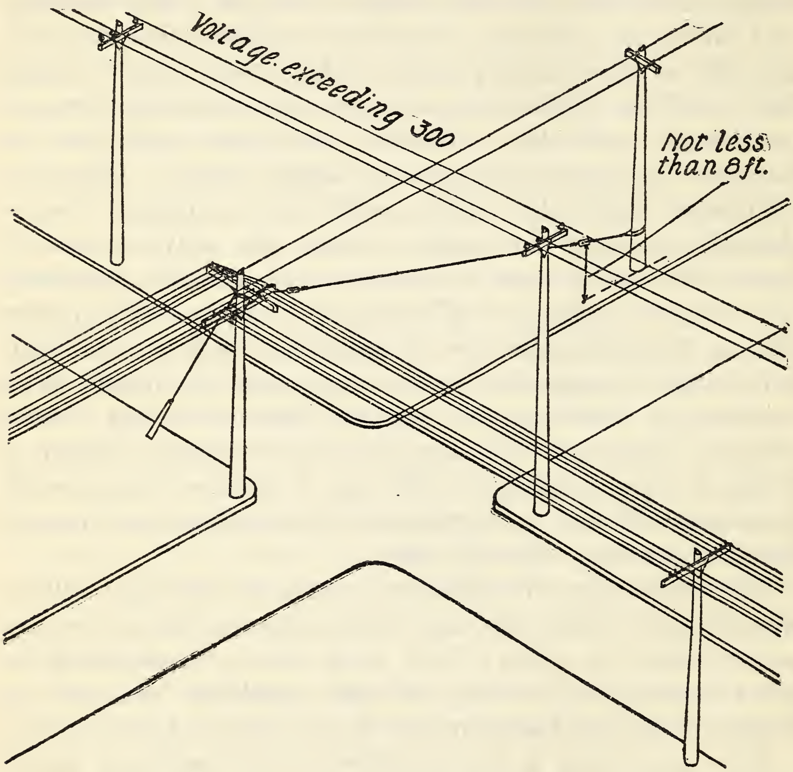

FIG. 26.—*Guy wire provided with two insulators*

The insulating value of a wood pole, especially when damp, is not to be depended upon, since it is often necessary for workmen on the pole to touch the brackets or span wires supporting a series lamp or trolley wire. It is general practice to provide double insulation between a lamp or a trolley wire and supporting metal poles in order to assure continuity of service. Therefore it would seem that where workmen are called upon to work on other circuits carried on wood poles, which also carry lighting or trolley brackets, as great precautions should be taken to protect their lives as are taken to insure continuity of commercial service when conductors are carried on metal poles, and that double insulation (not considering the pole as one) should be provided even with wood poles.

285. Conductors.

A. Identification.—In order to safeguard electrical workers it is necessary that lines should be arranged systematically by having conductors occupy definite positions throughout a system, as far as practicable. Failure to follow this practice leads to accidents to persons as well as lowering the grade of the service rendered. When arrangements of conductors are not uniform other means for ready identification of them should be provided.

Diagrams indicating the position of the various circuits and conductors, especially on the heavy leads and on corner poles, are valuable aids for the linemen and foremen.

Conductors and equipment should not be permitted to transfer indiscriminately from one pin or cross-arm position to another. A fixed scheme of arrangement, whereby series arc circuits, for example, would be maintained on certain pin positions of certain cross arms throughout the system, could be considered an identification. The more or less characteristic shapes and sizes of insulators for various voltage classifications frequently secure the desired result, though too much dependence should not be placed on this type of identification.

More or less elaborate schemes of line-conductor identification, by means of insulators of various colors or materials, have been devised. When properly maintained, such an arrangement is very satisfactory. Another suggestion frequently followed is to indicate on the cross arm opposite the pin position the character of the conductor according to a letter or number code. Sometimes a colored band or sign placed below any cross arm carrying conductors operating in excess of a specified voltage, or a distinctive color for the cross arm itself, has proved to be a useful identification. For instance, green may be employed as the color for cross arms occupied by supply wires of less than 750 volts, yellow for supply wires of 750 to 7,500 volts, and red for voltages exceeding 7,500. The workman is thereby readily enabled to determine the wires he may work on with impunity, those which require the use of rubber gloves or other protection, and those which require special precautions; as, for instance, the killing of the line, or specially designed tools.

B. Branch connections.

1. *Accessibility.*—Branch connections from a circuit made between supporting structures are undesirable. Their physical condition is hard to determine and maintenance is difficult. They also tend to pull line conductors together and to cause line breaks in the middle of spans. Workmen are unnecessarily endangered in making such connections from a ladder. Administrative authorities may be of assistance to utilities in this matter when unreasonable objections are made to conductors being carried from pole connections over private property to serve neighboring customers.

2. *Clearance.*—In making taps and branch connections care should be used to leave adequate working and climbing space for men who may later have to work on other circuits or equipment.

286. Equipment on Poles.

B. Location.—In selecting a location for a transformer other factors enter besides the question of load center. Junction poles or poles carrying complicated wiring should not be used for transformer locations, as maintenance work (such as replacing fuses or exchanging transformers) has very frequently to be done at night or in stormy weather. The less wiring there is in the vicinity of the transformers the safer will working conditions be.

In any case it is important to provide adequate climbing space all the way up the pole, so that it is not necessary for men to climb around the ends of cross arms, and also so that when climbing up the pole they will not injure crowded equipment with their tools or spurs.

Very heavy transformers are rather difficult to handle at the top of a structure and for this reason should not be installed on the top arm. There are various mechanical fixtures designed to facilitate the installation of large transformers on poles. It is the general practice in the case of jointly used poles to locate transformers of less capacity than 50 kva. in the upper or supply space. Heavy transformers should preferably be installed on a structure supported by or consisting of two or more poles.

C. Guarding.—Current-carrying parts of equipment should no more be permitted in the climbing semicircumference or quadrant of the pole than should unprotected vertical conductors. If 20 inches away from pole center and not in the climbing space (usually 30 inches square) or in the lateral working space parallel to line cross arms, a reasonable degree of safety is secured.

D. Hand clearance.—Even if such current-carrying parts are on the opposite side of the pole or above the climbing space (as with some pole-top fixtures) they should either be suitably inclosed and arranged for adjustment without opening inclosure or be so located that in adjusting them it is not necessary to put the hand or arm near other current-carrying parts at different potential or near a grounded part.

E. Street-lighting equipment.—A man climbing a pole will not always think of a lamp which he may be approaching with his head, and the lamp should be so placed as to give him sufficient clearance. In cities where the height of the lamp above ground is prescribed by ordinance, the location of the nearest cross arm, span wire, or pole equipment should be chosen so as to give ample clearance from the lamp. It is important on this account that lamp leads should be carefully located, and that the lamp cranes should be effectively insulated from the current-carrying parts. In the case of externally wired lamp fixtures, the construction should be such as to avoid the possibility of the wires coming into contact with the metal parts of the fixtures or its supports. This can often be accomplished by extending the vertical run on the pole to a point below the boom of the lamp fixture. Where the brackets are internally wired, care should be taken in protecting the insulation on the lead-in wires from abrasion at the point where they enter the bracket. Rubber insulation, in addition to a weatherproof covering, is recommended for these wires as well as for the vertical wires on the pole.

4. *Material of suspension.*—It is apparently not safe to use material for the lowering equipment of arc lamps which would deteriorate rapidly under ordinary bad weather conditions, or even from reasonable amounts of smoke, dust, or other flyings. At locations where large amounts of deleterious gases or dust are present, as near chemical works, blast furnaces, cement mills, etc., special materials should be used, and they should be inspected much more frequently than in other locations. Nonmetallic ropes have for some time been used generally for the lowering equipment of certain types of street lamps. The deterioration of these ropes is not due so much to wear as to the action of the elements. Their strength may be reduced very materially,

due to decay of the interior fibers, and still appear perfectly strong on the outside. The necessity for systematic inspection is evident. The nonmetallic ropes are particularly susceptible to the effect of climatic changes and have a life which, in some localities, may be as short as two years. They, therefore, offer a very serious hazard, not only to passers-by but to workmen as well.

5. *Insulators in suspension ropes.*—At the present time there are two types of materials commonly employed as lowering equipment for street lamps; namely, metallic chain or cable and manila or other nonconducting rope. The latter is generally used with the higher-voltage series direct current lamps in order to reduce the hazard occasioned by the voltage of the circuit. In such cases insulators are not necessary at the ground end of the rope. However, where the lowering equipment is metallic and therefore conductive in character the breaking down of the lamp cut-out may cause the lowering equipment to become charged with the potential of the line. An insulator should, therefore, be installed in the metallic chain or cable out of reach of the ground. On this account it is advisable to employ nonconductive suspension ropes especially where the lamps are placed on high-voltage d. c. circuits.

6. *Arc-lamp disconnectors.*—Even if series lamps are always handled from insulating stools or platforms, it is advisable to use disconnectors, so that the part which is lowered and which is worked on is dead.

287. Protection for Exposed Communication Lines.

Most overhead communication lines are or sometimes will be exposed to supply circuits exceeding 400 volts to ground at some point, so that it is undoubtedly advisable to provide one of the methods of protection given in section 39 of part 3 of this code.

288. Communication Circuits Used Exclusively in the Operation of Supply Lines.

A. Choice of method.—Circuits used for communication, closely paralleling high-voltage electrical transmission lines and used in the operation of the electrical supply system, may or may not normally carry a high potential to ground induced in them. In case the potential induced in such a circuit is indefinite or not limited by protective devices, the circuit, although used for communication purposes, invariably takes the status of a supply circuit and is to be installed in accordance with the requirements of rule 288, D, the conductors and the equipment connected to them being treated like supply circuits and equipment.

If the potential to ground of the circuit used for communication is normally not high and it is accordingly feasible to control the limit of the potential by protective devices, then the circuit may be installed optionally either as a communication circuit in accordance with 288, C, or a supply circuit in accordance with 288, D. When installed like a communication circuit, and at points on the line it crosses above or conflicts with other conductors or is above other conductors on the same pole, then the potential to ground must be limited to 400 volts by protective devices in accordance with the provision of rule 288, C, 2. When installed like a communication circuit and it is always below other conductors at crossings, conflicts, or when on the same pole, then the potential above ground may be limited in either of two ways, depending upon whether the normal potential is less than or greater than 150 volts. If normally less than 150 volts, the usual protective devices, including fuses and an arrester, may be used as required for communication apparatus by rule 390. If the potential to ground is normally greater than 150 volts, and even if greater than 400 volts, the circuit may still be installed along the line like a communication circuit, if it is equipped with protective devices that will limit the potential to ground to a value not exceeding one-half the breakdown potential of the insulation of the equipment attached to the circuit as required by rule 392.

This represents a special case where conductors may be installed like a communication circuit along the line, although their potential to ground exceeds 400 volts, if special conditions obtain including the following:

1. The conductors are used exclusively in the operation of a supply system.
2. The conductors are always below other aerial conductors at crossings, conflicts, and on the same pole.
3. Accessible apparatus connected to the circuit is suitably insulated, guarded, or grounded.
4. A protective device on the circuit limits its voltage to ground to a value not exceeding one-half the breakdown potential of the insulation of apparatus and equipment connected to it.

C. Where ordinary communication-line construction may be used.—If the requirements of C, 1, or C, 2, are met, no requirements as to strength of supports or sizes and sags of conductors need be met by the communication wires except at crossings over railroads, where grade D or E would apply. However, as regards the construction of the supply wires, the communication wires will not be considered as such, and the supply wires and supporting structures will not thereby be required to comply with the grade of construction which would apply where they are concerned with communication circuits for public use. The supply wires must not, however, be smaller than required for grade C. (See rule 242, C.)

289. Electric Railway Construction.

A. Trolley contact conductor supports.—When a trolley pole slips from the contact wire, it not infrequently breaks the trolley wire loose from its supporting span or bracket suspension wire. It is desirable and reasonable to require that if the trolley wire becomes loosened from one hanger, or if one suspension span fails, no part of the trolley contact wire or its current-carrying parts come closer than 10 feet to any generally accessible place.

B. High-voltage contact conductors.—As voltages become greater the danger rapidly increases, and it seems entirely reasonable to require that where voltages of more than 750 are used on overhead trolley contact conductors in thickly settled communities the supports should be so frequent that even a break in the trolley conductor itself could not permit its falling to within reach of passers-by or so low as to obstruct traffic.

C. Third rails.—Third rails have come into use on many interurban electric railways, but on account of the difficulty of providing adequate protection are seldom installed in locations which are open to the public. However, where they are so located the necessity for some kind of protection is very evident. This protection is best obtained by the installation of a continuous insulating strip or strips placed above the rail. The construction is, perhaps, the simplest and safest when the underrunning type of rail is employed, as the possibility of accidental contact is greatly reduced, and the operation of the railway under severe weather conditions is considerably improved. It is impossible to entirely prevent contact with live parts, and on this account the warning to the public by suitable signs is recommended, and also the elimination of third rails excepting on private rights of way, elevated, or underground structures.

D. Prevention of loss of contact at railway crossings.—Because of the greater clearance of trolley required at railway crossings than on the highway, the trolley pole at such places takes a nearly vertical position. The trolley springs are so adjusted that they are not in tension when the pole is in the vertical position. Thus, the greater the elevation of the contact conductor the less effective is the trolley-pole spring and, therefore, the less the pressure of the trolley wheel against the conductor. Because of this reduced pressure the jar of the car passing over the crossing can easily cause the wheel to slip from the trolley wire. By placing an inverted trough above the trolley wire so arranged as to catch the wheel should it leave the wire the car will be assured of power and thus will not be obliged to stop on the crossing. Another expedient sometimes adopted has been that of maintaining the trolley conductor in the spans immediately adjacent to the crossing span at the same elevation as the crossing, thereby reducing the effect of a sudden change in level. Even in this case, however, the trough is recommended.

Such special construction is not necessary where pantograph trolley with rollers or shoes is employed.

E. Guards under bridges.—The foregoing recommendations cover also the protection of the trolley conductor where the electric railway passes beneath a metallic bridge, except that here the guard must be of insulating material. The accidental short-circuit produced between the trolley wire and the bridge should the trolley pole leave the wire would probably burn the wire down.

Sec. 29. RULES FOR UNDERGROUND LINES

290. Location of Duct Systems and Manholes.

A. General location.—The municipality will usually prescribe the general location of an underground installation, and existing piping will be a determining factor. If given some freedom, a utility can eliminate much trouble and expense by a careful study of the existing underground structures, together with those being planned for the future.

This may permit of more liberal manhole dimensions than are frequently provided in congested districts.

B. Ducts.—Ducts should be installed in straight lines but may, where necessity arises, be installed with curves, in which case the radius of curvature should be as great as possible. If curves of short radius are used, cable when being drawn through the duct may drag hard around such a curve, and the lead sheath may be damaged either by scraping against the duct or by stretching.

C. Manholes.—So far as practicable the entrance to underground construction should be so located as to assure safe access or exit. A workman should have sufficient room to permit raising his head above ground without being struck by a moving car, and in case of accident in a manhole he should be able to get to the surface readily.

291. Construction of Duct Systems.

A. Material, size, and finish of ducts.—There are a number of different duct materials, among which may be named vitrified clay, stone or concrete, fiber, and wood. The first mentioned is used more generally for telephone work, as it adapts itself most readily to construction, especially in multiple arrangement, and on account of its smooth finish and fireproof qualities. Fiber offers some advantages, as it is readily laid and is not liable to breakage as is clay duct. It is highly important that the interior of all ducts be smooth and free from projections, so that cable may be readily installed and removed without damage to the sheath. In order to prevent as far as possible trouble in one duct due to a burnt-out supply cable communicating to cables in adjacent ducts, single ducts offer some advantage, as the joints may be staggered and, in addition, a double wall is provided between cables.

B. Grading of ducts.—It is very important that ducts be so graded that all moisture can drain toward the manhole.

If pockets are left in the duct line where water can gather the cables may be damaged in winter through freezing of the water.

C. Alignment of ducts.—When ducts are laid carelessly, shoulders occur between adjoining sections of the ducts. These sometimes make it impossible to install a cable, while frequently the sheath is badly damaged.

D. Duct joints.—Ducts should be so designed that perfect alignment may be maintained during construction. In multiple clay conduit, holes are usually formed in the ends of each section of conduit and dowel pins are used to keep the alignment, while in fiber ducts the alignment can be obtained by use of sleeve, drive, or screw joints. In the case of laying single-duct clay conduit the alignment is generally maintained by use of a mandrel which is longer than each section of duct and slightly smaller than the bore and is advanced through the bore as fast as the duct is laid.

E. Protection.—Where soil is soft and unstable, suitable foundations should be laid for conduits to rest upon. These may be plank, concrete, or other materials, while in solid ground a suitable foundation may be provided by tamping the natural soil securely into place. When making excavations in a street, workmen frequently break into a conduit. Aside from the property damage, accidents occur from injuring the cables and their sheathing. It is sometimes advisable to provide covers to reduce this trouble. Good modern practice provides such protection at locations where it is needed. Ducts are embedded in concrete, generally at least 3 inches thick.

F. Clearances.—Conduits should be located as far as possible from other underground structures and especially from water and gas mains. Water from a broken main might undermine the conduit system, causing it to settle or even break. Gas leaking from its pipe will often find its way

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through considerable earth to a manhole. Thus, the greater distance between such systems the less are the chances of damage.

G. Separation between supply and communication duct systems.—To arrest the action of an electric-power arc and not to permit it to affect communication cables, a barrier wall of concrete not less than 3 inches thick should be placed between ducts carrying supply conductors which are adjacent to those carrying communication conductors when the supply circuit is of limited energy due to automatic devices or through being part of a small system. For conditions where the energy is great this barrier should not be less than 6 inches in thickness. This same means of limiting damage by cable arcs is often advisable for use between conduits containing large supply feeders used for different classes of service or acting as important tie lines between different stations.

On account of the great cost of underground construction it is considered proper to allow the extension of communication and supply cables in existing jointly used duct lines which are not installed with sufficient separation as provided in this rule, if the proper precautions are taken in the manholes as given in paragraph 2.

When a supply cable fails, the arc caused may communicate the trouble to other cables in the same manhole. If communication cables and supply cables were close together, trouble originating in the supply cable might be communicated to the communication cable. When it is necessary for both classes of lines to use the same manhole, they should naturally be separated as far as possible. This will also tend to prevent service interruptions.

H. Duct entrances into manholes.—The minimum clearance of 6 inches from duct openings to the roof and floor of manholes is to provide a convenient working space and to protect the workman.

To prevent abrasion of cable sheaths at the sharp corners of a duct where entering manholes, shields should be provided between the edge of duct and cable. Galvanized shields are sometimes used, as well as sections of sheathing cut from old cables and flattened, while felt is also used.

I. Sealing laterals.—Whenever laterals are run as services to buildings through which moisture or gas may enter the main system or manhole, the duct should be suitably plugged.

J. Duct arrangement for dissipation of heat.—In a duct system the ducts in the center will dissipate less heat than those on the sides or corners. In locating cable positions those of heaviest capacity should be placed in the corner positions and those of lowest capacity in the center. Ducts if grouped in large numbers can not be relied upon to dissipate the heat properly, and thus should be limited to a reasonable number.

292. Construction of Manholes.

A. Minimum strength.—It is not contemplated that every manhole cover should sustain the heaviest loads. They should provide strength in accordance with the conditions it is reasonable to presume will be met. During the process of installation many utilities require that suitable eyes or hooks be embedded in the concrete or brick walls of manholes, so located with respect to the duct-line entrance as to facilitate the installation and removal of cables.

B. Dimensions.—It is believed that the dimensions indicated can usually be provided in manholes and are the minimums to provide a reasonably safe working space and also to give a workman a fair chance to get out in case of accident. The inside dimensions are especially important where transformers are to be installed in manholes. Sufficient space should be provided to safely and readily operate the cut-outs which are necessary with transformers.

C. Drainage.—The apparatus and cables in manholes are not accessible when covered with water. Where water is present, sediment is deposited on the apparatus and walls of the manhole which makes much cleaning necessary before work can be done in the manholes. Thus, it can be seen that well-drained manholes are desirable. Where drains lead directly into sewers, traps should be so installed that sewer gas can not enter the manhole. Sewer gas is dangerous on account of the asphyxiating effect due to the lack of sufficient oxygen content. Its presence is, however, generally evidenced by the sulphide of hydrogen caused by the decomposition of organic matter in the sewers. A poisonous effect is produced by the presence of sulphides of ammonia and hydrogen, which, combined with carbon monoxide and methane, may produce an explosive mixture. All of these characteristics combine to make sewer gas extremely objectionable in manholes.

D. Ventilation.—Illuminating gas from near-by defective gas mains may find its way into a manhole. Illuminating gas is poisonous and highly explosive and therefore very undesirable to have in manholes even in small quantities. Arcs occurring in manholes filled with gas have caused explosions which have not only damaged streets but near-by property and have injured persons in the vicinity. When ventilating manholes, care should be taken that the ventilating shaft is so located that surface water can not enter it.

The ventilating ducts or shafts are naturally very valuable from an operating standpoint, as a reduction in temperature will materially increase the capacity of underground apparatus, particularly transformers. Permanent fans may be employed to increase the effectiveness of the ventilators. The effect of high temperatures is very marked on workmen engaged in installing apparatus in such manholes.

E. Manhole openings.—Ordinarily a manhole entrance 24 inches in diameter will provide sufficient space for ready exit.

A manhole cover which is circular is preferred. Square covers may slip down into the manhole.

F. Manhole covers.—A cover for a manhole or handhole which has sufficient weight to hold it in place is considered secure. Locking or clamping is not required, although frequently advisable. A special hook or bar is frequently provided for opening a manhole, while some covers have a recess in the top crossed by a bar, and a spring snap attached to a strap is hooked onto this bar, thus providing a special and safe means for removing the cover.

G. Supports for cables.—Shelves of fire-resistive materials provide excellent means for supporting cables in a manhole, while their use practically assures that an arc will not spread to create much damage. Since short circuits do sometimes occur, the best means for avoiding extensive burn outs and failures of service or injuries to persons and conductors should be sought. Cables should be so routed and subdivided that a minimum number are involved in any one failure. This precaution is especially necessary where a high voltage exists and low-voltage feeders not provided with automatic protection are involved.

293. Manhole Location.

The usual type of collapsible rail guard made of pipe or angle iron is considered as a suitable guard for manholes when the cover is removed. It is also desirable as an extra precaution to attach a red flag or warning sign or both to the guard. When manholes are located near track rails and guard rails can not be used, the hole should be covered with a grating of iron bars as a protective measure. During rainy seasons a manhole tent will serve as an effective guard or warning sign, and, in addition, keep the manhole free from rain. It is generally preferable that a workman be stationed above ground, if possible, but in many locations this will not be necessary.

294. Location of Conductors.

A. Accessibility.—On account of the limited amount of space in manholes, cables should be carefully racked and so spaced and located that they are readily accessible at all times to the workman. When cables are crowded together with insufficient working space about them, the work performed upon them will be inferior to that performed on cables which are readily accessible.

The splicing of supply cables is a very important and particular operation. Joints probably give more trouble than any other part of an underground system, due to failure of insulation, overheating on account of poor contacts, and to entrance of moisture through poorly wiped joints in the lead sheath. They also require inspection from time to time to determine if they are heating excessively or if other defects are beginning to show. Thus, the importance of locating joints in readily accessible places and not in ducts between manholes is evident.

D. Separation between conductors.—In order to reduce the possibility of damage to low-tension cables by arcs in case of failure of high-tension cables, the two should be separated as far as possible.

Where practicable in underground construction, supply and communication lines should, as with overhead construction, be given separate routes. In overhead lines a conflict or joint use of poles, where a separate route is impracticable, causes some additional hazard which is met to a reasonable degree by compliance with the required grade of construction.

In underground construction, as with overhead construction, consideration of expense in providing separate routes for supply and communication lines, or lack of room in a street where both utilities were installed, has sometimes necessitated the use of a single conduit line for both utilities. A somewhat greater hazard undoubtedly exists than with separate conduit lines but less hazard than with overhead construction in general, since hazard is mainly confined to employees, and the public is rarely endangered by underground lines. Where the supply lines are of high voltage or of very large capacity, it is still more desirable to keep the two kinds of systems separate.

When, however, both systems are installed in a single conduit line, the requirements of the rule are considered, in general, to provide a reasonable degree of safety for workmen and public.

It does not seem reasonable to require cable extensions in jointly owned or occupied duct systems to be separated, but they may be continued as in the original installation.

As has been stated before, it is desirable to have supply and communication cables occupy opposite sides of the manhole.

At times it is necessary that communication cables cross supply cables, but when so doing they should be separated by at least 1 foot and should be further protected from damage by some form of mechanical protection. Several methods of protecting cables from arcs are as follows: Concrete barriers, asbestos tape saturated with silicate of soda, asbestos tape covered with a band of soft steel armor, split tile duct with cemented joints, and a cement coating covering the cable.

295. Protection of Conductors in Duct Systems and Manholes.

A. Protection against moisture.—The insulating coverings other than rubber of all cables or conductors shall be protected by a waterproof covering. In general, a continuous lead-sheath cable is very desirable. However, other forms are sometimes used.

296. Guarding of Live Parts in Manholes.

Where metal sheathing is used on cables it should be made continuous electrically and mechanically with the cases of equipment, such as switches and transformers. Where metal sheathing is not used, the conductors should enter cases of equipment through openings which have proper bushing or gaskets to insure water-tight joints.

Underground current-carrying parts when exposed to contact in manholes and handholes are a source of great hazard and should not be allowed to exist. Live parts of transformers, switches, fuses, lightning arresters, or other apparatus should be inclosed completely as a protective measure.

297. Construction at Risers from Underground.

By using ordinary taped joints where conductors from lead-sheathed cable connect to open conductors of overhead systems a weak point is made in the system. By use of suitable potheads the insulation is protected from injury by electrostatic discharges or by moisture. The conductors are separated properly from each other and from the grounded metal sheath and are sufficiently insulated. Also good electrical contacts are made, and the whole structure is rigid.

298. Identification of Conductors.

For the safety of workmen it is very important to have all cables plainly identified in every manhole. Identification may be made by use of metal tags, stenciling of the cable, or by charts showing the position of the cables. When tags are employed for this purpose, a noncorrosive material should be used, and the marks should be such that they are not easily obliterated. A supply circuit should be identified by name or number, size of conductor, and voltage of the circuit. As an additional precaution it is important that a uniform method for installing the cables in the ducts be followed throughout, or at least as far as possible. For instance, it is customary to install the local power distribution cables in the top ducts of a duct line, not only, however, to facilitate their identification but also to permit the installation of an intermediate service hole, which requires access to these cables only, between manholes.

299. Identification of Apparatus Connected in Multiple.

When multiple connections are maintained between different transformers in underground construction, a very positive means must be provided at each such transformer to indicate that fact. A serious hazard exists if a repair man disconnecting such a transformer from the high-voltage source of energy believes that it is entirely dead, while in reality it is energized through the low-voltage connection. Such connections should be used as little as possible, and in any event their existence should be indicated clearly to workmen.

Parallel operation between an overhead and an underground transformer is still more hazardous, as different groups of workmen are usually involved on the two classes of construction. This is also true when underground lines are arranged in the form of loops to facilitate their operation and to confine any necessary interruption to the smallest possible sections. Any switches used for sectionalizing purposes should indicate clearly the position of their mechanism.

Part 3.—RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRIC UTILIZATION EQUIPMENT

Sec. 30. SCOPE OF RULES AND GENERAL REQUIREMENTS

300. Scope of the Rules.

In workshops, mercantile establishments, and similar places more reliance must be placed on physical guards about the current-carrying parts of electrical utilization equipment and less reliance on working methods than in supply stations, where station equipment only is concerned. As a general principle all such current-carrying parts should be guarded except those requiring frequent inspection and repair by authorized employees, and these parts should be made inaccessible to other persons. Parts at very low voltages may be considered as exceptions to this general requirement for guarding live parts, since the degree of danger is so much less than with higher voltages.

(a) **Voltage limits and occupancies.**—The rules cover equipment between 25 and 750 volts. The upper limit was set sufficiently high so as to include voltages at present in common use under circumstances where station conditions and attendance are not approximated. In a few cities 440-volt, three-wire, two-phase circuits, with approximately 615 volts between two of the wires, are in use, and voltage regulation may require parts of these circuits at times to be slightly above this value. The 750-volt limit will include this type of circuit in the rules. It is not intended to encourage the increase of present utilization voltages.

The lower limit of 25 volts will include most circuits and equipment that really fall into the hazardous class. Isolated plants of 32 volts would, of course, come under the rules. Many interior signaling circuits are exempt, and rightly so, since they are usually operated from batteries at voltages lower than 25.

Some apparatus, such as battery chargers, employ transformers for stepping down the voltage of the house-lighting circuit to values less than 25. Formerly autotransformers were used which did not isolate this low-voltage circuit from the higher-voltage house circuit. In this case the lower-voltage circuit certainly falls within the scope of the rules. The later types of this apparatus employ separate-coil transformers and therefore completely insulate one circuit from another and so minimize danger to persons making connections to the battery.

(b) **Equipment of more than 750 volts.**—Where conductors are of more than 750 volts they should be entirely ironclad; that is, entirely incased in metal conduit. Interior alternating-current power circuits of 2,300 volts are used to some extent in industrial plants where there are a few large motors, but in installations of many small motors the lower voltages have usually proved more practical and safe.

(c) **Utilization equipment regarded as supply equipment.**—In industrial plants where equipment of any voltage is isolated in a separate locked room subject to the supervision of the plant electrician or other qualified attendant, it need not come under the rules of part 3. The rules of part 1 for stations apply in that case.

The subject of persons involved in the use of electrical apparatus has been given much thought by various committees of technical organizations. There are three classes of persons to consider—first, the ordinary public or the passer-by; second, the authorized operator; third, the qualified person. For the authorized operator the same degree of protection should be provided as for the ordinary person or the passer-by, the only difference between the two being that one handles equipment though he is not necessarily familiar with the hazards due to live electrical apparatus, and the other does not intentionally come in contact with it. A lesser degree of protection is sufficient for the qualified operator, as he is an individual who is supposed to handle live parts, this class being intended to include maintenance men, repair men, and others, who must adjust or in any way handle current-carrying parts of apparatus which are not dead. Usually his qualifications are of little value if his attention is given to industrial processes and therefore distracted from the purely electrical conditions. For such persons it may be a greater hazard to have adjacent non-current-carrying parts grounded than to have them insulated. On the contrary, for the person who merely has access to cases, frames, etc., but not to live parts, the hazard is always reduced by having accessible parts grounded. Consequently, a distinction should be made as to persons having access with respect to the protection to be furnished through grounding or through insulating.

301. Application of the Rules.

(a) **Waiving of rules.**—It will, in general, be found less frequently advisable to modify or waive the utilization rules than may be permissible with station or line rules, since the modification or waiver of a station or line rule can be accompanied by an appropriate change in operating precautions or working methods in which the workmen can be duly instructed. Electrical operating precautions for workmen whom it is not feasible to thoroughly instruct in electrical operation, and whose attention must be principally given to other processes can not, however, be considered equivalent to the provision of physical safeguards such as are called for in the utilization rules.

Experimental installations and methods of construction and operation should, in general, be allowed by administrative authorities whenever they are satisfied that the experiments entail no excessive hazards and will probably lead to improvements in the art. The administrative authorities under such circumstances should sufficiently supervise and subsequently inspect the experimental installations so that their advantages or disadvantages may be determined in comparison with the methods specified in the rules.

(b) **Intent of rules.**—It is the purpose of the rules both to indicate principles of protection and means to facilitate compliance with these principles. Numerous devices are now offered by manufacturers embodying safety features that will meet the requirements of the rules, and installation of these together with proper methods of construction involving safety features will assure a reasonably safe and standard installation. Manufacturers are developing new apparatus and improving existing devices with safety in view.

Old installations can in many instances be brought partly or wholly into compliance with the rules, sometimes at slight expense.

(c) **Temporary or emergency installations.**—In some instances installations are of a temporary nature or nearing the end of their useful life, or changes for other reasons than safety are shortly to be made, and the expense involved in bringing them into compliance with the rules would not be justifiable. In such cases it will be proper to waive the rules if sufficient assurance of the temporary nature of the installation is given to the administrative authority. Emergency installations may be made following fires, floods, etc.

302. General Requirements.

(a) **Approved materials.**—Electrical equipment is available from reliable manufacturers to meet the requirements of these rules. Proper care, however, must be exercised to select equipment which is satisfactory both for the work to be done and for the location where it will be used. Before proceeding with an installation careful study should be made of the atmospheric conditions, character of load, and the probability of hazardous processes.

After equipment is once installed no change in operating conditions should be made until it is known that the equipment is capable of safely meeting the new conditions. In selecting material or devices to properly meet conditions in compliance with the rules, reference to reports on these materials or devices, by Underwriters' Laboratories or other properly qualified body, will remove the necessity for frequent repetition of tests on the same materials or devices in different cases, and such uniform examinations and reports are of great assistance to manufacturers and users alike, in assuring that the products concerned meet a reasonable standard of safety to life and property.

Some States and some cities have established testing laboratories for the purpose of testing materials and devices to determine their suitability for the purpose intended.

(b) **Future inspections.**—See discussion of rule 111. The inspection of electrical utilitization equipment and wiring before placing it in service is even more important than with station equipment, since the operator of station equipment may, by reason of his electrical training, be relied upon to some extent to detect and repair or remove defects which may endanger property or life, whereas utilization equipment will not be under such constant expert observation and any electrical defects may go unnoticed and uncorrected until an accident occurs.

A systematic inspection should be given to electrical utilization equipment of all kinds. Such inspection will aid in detecting abraded or oil-soaked insulation and similar defects before they become serious or cause accidents or interruptions to service. Such inspections should be made by properly qualified employees at reasonable intervals, according to the character of the equipment and the severity of the conditions to which it is subject. Much can also be done, through occasional inspections by owners or tenants, toward eliminating abraded portable cords supplying mechanical protection to wires in exposed locations and like minor matters.

It is of importance not only to install the initial equipment according to best accepted practice but also to keep it in good repair thereafter. There are numerous ways in which electrical equipment may become defective, deteriorate, or fail to perform its functions properly. Some of the more common causes are corroded and loose connections, worn insulation, loose fastenings due to wear, mechanical injury (as during building repairs), accumulation of dust and moisture. Corroded and loose connections tend to cause arcing and sparking at the loose parts and sometimes may cause complete interruption of the circuits. This condition creates in turn fire and personal accident hazards. Mechanical injury may cause impairment of the functioning of switches, sockets, and devices of like character and may render useless safeguards, such as railings, inclosures, guards, etc. This condition may remain for a long time unless the need for repairs is seen immediately or discovered by inspection and the necessary repairs made.

While the rules do not prohibit the use of open wiring, such wiring should be arranged uniformly and neatly and kept orderly so as to reduce the life hazard as much as practicable.

Equipment should be frequently cleaned. The accumulation of grease and dust seriously impairs the performance of electrical apparatus, and in addition the accumulation of dust around arcing and sparking parts represents a fire hazard. It is especially important to keep glassware and shades provided for electric lights free from dust. The accumulation of dust on shades reduces the amount of illumination very materially and may be the source of accidents besides causing eyestrain to those using and working under the improperly cleaned and maintained lighting units.

A useful blank form as a guide and record in making initial or subsequent inspections is shown in Figure 27. While this form is designed for inspecting and checking house wiring installations by an electric utility company, similar forms may be devised to meet the needs of insurance or city inspectors for this type and also other types of installations.

To maintain electrical equipment at a proper standard, any necessary repairs should be done only by properly qualified persons. A machinist, a coal miner, or a householder can hardly be expected to repair motors or wiring the use of which is incidental to the work in which he is engaged, as well as would a qualified electrical workman. Many accidents occur from defective electrical equipment, the defects of which are the result of attempts at adjustments or repairs by persons not properly qualified to do such work.

303. Reference to Other Codes.

The National Electrical (Fire) Code covers interior wiring in greater detail than this code, and all wiring and appliances should be installed in compliance with it. That code is a set of rules which have been the standard of practice for many years, covering electrical installations from the viewpoint of fire hazards. It is revised from time to time by the Electrical Committee of the National Fire Protection Association and published by the National Board of Fire Underwriters.

It has been demonstrated that accidents happen more frequently in dark and poorly lighted places than in those where the light is adequate and objects can be clearly seen. It is consequently desirable in attempting to reduce accidents due to contact with live parts or with moving machinery, as well as accidents due to stumbling, collision with pro-

[illegible]

INSPECTION REPORT

THE TRINIDAD ELEC. TRANS. RY. & GAS COMPANY.

№ 23273

Name of Tenant.................................... Street address ....

Name of Owner.................................... Address of Owner....................................

1 Are there any light fixtures or wiring in close proximity to iron pipes, radiators or grounds where contact can be made simultaneously in any manner?....................................If so, give full description

....

2 Can light fixtures or wiring be reached by a person using telephone?....................................

3 Distance of telephone from nearest light fixtures or wiring, in feet....................................

4 Are porcelain or mica sockets used in bath rooms, kitchens and other places where contact might be made from lamp socket to a pipe, range, bath tub or other grounds by a person reaching from one to the other?..........

5 Can fixtures in bath room or wash room be reached while standing in tub, or handling water faucet?..........

6 Are there any lamp stands or portables with defective insulation or grounds?....................................

7 Are there any open knife switches or other unapprove types of switches used?....................................

....

8 What are the general conditions of the wiring and light fixtures inside the house?....................................

....

9 Are the service wires entering the house out of harms way, and are they so placed that contact cannot be made by persons carrying objects, or by persons climbing on top of coal sheds, other buildings or porches?......

....

10 In case of a broken service wire, would it fall on telephone lines, clothes line or building?....................................

....

11 In case of a broken telephone lines, would it fall on electric light wire?....................................

....

12 Is there any possible chance for meter to be bypassed? ....

13 Were there any grounds in the premises?.................................... Where....................................

14 Did you clear grounds and other defects, if any?....................................

15 Did you notify the consumer of defects and the nature thereof, in writing?....................................
(Attach copy of notice, if any, hereto).

16 What voltage at time of inspection?....................................

Examination made by.................................... Date.................. Noted by.................................... Date..................

State below correspondence by office and notification on the above conditions.

....

....

....

....

....

....

....

....

The above was re-inspected on....................................and found or not found changes had been made as recommended.

Signed ....

For remarks use other side.

FIG. 27.—*Sample blank for inspection record*

95197°—28——16

truding parts, etc., to provide sufficient illumination to discern all objects clearly.

In the Code for Lighting Factories, Mills, and Other Work Places, published by the Illuminating Engineering Society, values are given for the intensity of illumination which should be the minimum permitted under various conditions and also the values which are considered good practice. Experience has shown that in industrial plants having adequate lighting, production is increased and defective work greatly reduced by the provision of ample illumination properly arranged, and it frequently pays to provide intensities much higher than those given in the Industrial Lighting Code, above mentioned. The rules of this code cover also elimination of glare, the proper distribution of light, and provision for emergency lighting. The latter is needed in crowded workshops or in those having moving machinery or exposed live parts in order to permit safe egress from the premises in case the regular lighting system should fail.

Industrial lighting codes are mandatory in the States of Pennsylvania, New Jersey, New York, Wisconsin, Oregon, Oklahoma, Washington, Massachusetts, California, and Maryland.

The National Safety Code for the Protection of the Heads and Eyes of Industrial Workers has been published by the Bureau of Standards. It contains specifications for goggles and helmets suitable for protection of the worker in doing welding work and when exposed to severe arcs, etc.

The Safety Code for Elevators, Dumbwaiters, and Escalators is published by the American Society of Mechanical Engineers under the joint sponsorship of that society, the American Institute of Architects, and the Bureau of Standards. Its regulations regarding elevators include certain items applicable to the electrical equipment.

304. Grounding.

(a) **Grounding method.**—See discussion of rule 113, (*a*).

(b) **Circuits required to be grounded.**—The grounding of electrical circuits and the grounding of the frames of the equipment to which these circuits are connected has long been recognized as a protective measure, as it considerably reduces the hazard to persons who use, operate, or otherwise handle or come in contact with those circuits and the metal parts of the equipment. Various ideas and methods are used in different localities, all of them affording some degree of protection, but the desirability of standard practice in this respect can not be too strongly emphasized. The rules of section 9 as well as rule 304 represent much thought and study of this subject, and compliance with them will assure a safe and standard installation.

Many distribution circuits are at times more or less grounded by passing through and touching numerous tree limbs. The leakage from this cause and the general leakage through the high-voltage apparatus may be appreciable. If the distribution circuit is very long, it is not necessary for any leakage to be present in order to obtain a current from any one of the primary lines to ground, and the electrostatic charging current for the primary conductors is nearly always high enough to produce a fatal shock under some conditions. The electrostatic potential to ground may readily be of sufficient magnitude to cause a fatal shock, though it will not operate the station circuit-breaker nor blow the transformer fuse in the event of a ground on one wire. This condition would produce a serious hazard in the event of a cross between the primary and the secondary, if the latter is ungrounded or inadequately grounded. Therefore, all circuits which are so exposed to other circuits that their voltage may be increased by contacts with them, or by breakdown between transformer windings or by electromagnetic or electrostatic induction, should be either recognized and guarded as circuits of the highest voltage to which they are exposed or should be so grounded that a dangerous increase of voltage can not take place between them and the ground or conducting objects, such as telephone equipment, radiators, and plumbing, which are intimately connected with the ground. Guarding low-voltage devices and circuits sufficiently to protect against high voltage is impracticable, and protection must therefore generally be by grounding.

Certain cases occur in which the advantage of grounding the circuit seems insufficient to warrant its requirement, as follows:

(1) Two-wire direct-current circuits of isolated plants are frequently entirely unexposed to higher voltages and the grounding can not decrease while it may increase the liability of shock to persons coming in contact with current-carrying parts or frames of connected apparatus. Two-wire direct-current commercial circuits are likely to be underground and unexposed, but even where carried overhead so as to be exposed they may, by grounding, cause electrolytic damage. The balance of advantage is considered by many to lie with the insulated system, and grounding is not required. (See rule 92, *a*.)

(2) Circuits unexposed to higher voltage either directly or indirectly are not necessarily made safer by grounding on one side, and may even be made more dangerous than they would be if kept entirely free from grounds. If of large extent and serving many consumers, the chance that they can be kept entirely free from grounds is, however, so remote that usually the ground connection is harmless and may reduce unexpected hazards from unknown exposures to higher-voltage circuits. No ruling is made on this point, and the judgment of the utility will govern in the absence of action by the local authorities.

Where unexposed circuits are three-wire (not three-phase) a great advantage follows the grounding of the neutral, since the voltage to ground of connected apparatus can then be only one-half what it might become through accidental grounding of an outer wire on an ungrounded circuit; and in practice such accidental grounding, often slight, but sufficient to cause dangerous shocks, is recognized as a common circuit condition. This advantage is so pronounced that even with direct-current three-wire circuits it is believed to overcome the disadvantage of possible electrolytic damage and, in general, to call for the grounding of the neutral, although in this case such grounding should be restricted to one point of the circuit. Such circuits are usually so grounded in practice, even where run underground or otherwise entirely unexposed to higher-voltage circuits.

(3) Circuits of more than 150 volts to ground are not definitely required to be grounded, since serious shocks are possible from the normal circuit voltage, and these would not be eliminated by grounding, but guarding must be depended upon for protection in any event. By definition 12, and rule 306, it will be noted that dependence is placed upon guarding rather than on the insulating covering of conductors, since this is not considered suitable as a guard for ungrounded circuits, even of less than 300 volts, if these are elsewhere exposed to leakage from higher-voltage circuits, although sometimes permissible for grounded circuits up to 300 volts where not exposed to mechanical injury, as near floors. Many engineers consider grounding highly advisable for the highest-voltage circuits used for utilization equipment if these circuits are exposed to leakage from higher-voltage circuits, since it is impracticable, as noted above, to provide devices or circuits with sufficient insulation to protect against high voltages which might be imposed on them by crosses in storms or from other causes.

(4) Arc-furnace circuits, unlike secondary distribution circuits, involve a comparatively small number of persons in any probable handling of the conductors intentionally or accidentally. The intentional handling is usually done by a qualified person. In the newer furnaces all bare parts of the switchboard, such as contactors, are inclosed to exclude dirt and dust and unauthorized persons. The secondary cables feeding the furnace are generally placed 8 or 10 feet from the floor. Taking into account the above, together with the fact that primaries feeding the furnace transformers are generally of large capacity, it follows that a ground connection on the secondary for protective purposes would necessarily have to be of extremely low resistance; therefore, it is considered proper to permit rather than require the grounding of furnace circuits.

The induction furnace need not have its circuit grounded because the voltage is high and nothing would be gained by grounding.

Resistance welder circuits are generally low-voltage secondaries of less than 25 volts and would not come under the rules.

Arc-welding circuits are usually grounded for operating reasons.

(c) Grounding noncurrent-carrying metal parts.—See discussion of rule 113 (*b*).

Parts of the apparatus which are normally not current-carrying sometimes become alive through failure of insulation. Grounding will prevent the existence of a dangerous voltage on noncurrent-carrying parts, such as transformer frames and cases, motor frames, and conduits. The higher the operating voltage of the equipment the more imperative is the necessity for the protection afforded by such grounding. In locations where explosive gases are present grounding is also necessary, even at the lowest voltages, since even a small spark, due to leakage current from an ungrounded frame to some conducting material in the vicinity which is in contact with the ground, would be liable to cause an explosion. Where equipment is located so that workmen might otherwise unsuspectingly receive a shock by coming in contact with the equipment frame, by reason of the existence in the immediate neighborhood of well-grounded surfaces, such as those provided by plumbing fixtures or damp floors, the grounding protection should be provided even with equipment operating at the comparatively low voltage of the common 110-volt system.

There are a few exceptions where noncurrent-carrying parts may be left ungrounded. In direct-current trolley circuits it may be desirable and more safe to insulate frames of switchboards from ground because there are usually bare current-carrying parts on such boards with which a person may come in contact and at the same time be in contact with the frame. In this case a grounded frame would cause a serious shock, whereas if well insulated from ground no injury to the person would result if standing on an insulated floor. Where such boards are left ungrounded there should be no grounded parts such as conducting floors, plumbing, etc., within reach. It is also desirable in some cases to insulate the frames of motors, cases of fixtures, and other noncurrent-carrying parts connected on direct-current trolley circuits, because of the fire hazard if such parts were grounded.

It is not necessary to ground small parts where the possibility of their accidentally becoming alive is remote.

In the case of short lengths of conduit used for the protection of wiring on side walls, it is not necessary to ground, as the likelihood of the pipe or conduit becoming alive is extremely remote and their small extent makes personal contact less likely. Where not permanently grounded they should be well insulated. There may be other special cases where no added safety may be had by grounding.

The permitting of service conduit to be left ungrounded is justifiable where such conduit is insulated from the other metal work and ground and is not within reach from grounded surfaces. This case is often found in actual practice, and no added safety would be obtained by grounding. At places where the service conduit comes within 8 feet of a grounded surface a special guard may be used to prevent persons touching it and it would then be considered out of reach.

305. Working Spaces about Electric Equipment.

(a) **Adequate space.**—Failure to properly guard moving parts of machinery where crowded gives rise to one of the most hazardous mechanical conditions in workshops. The exposure of live parts of electrical equipment employed in connection with the machinery of workshops is a similar hazardous condition, the hazard increasing with increasing voltage. With restricted working space and inconvenient access, electrical equipment is also likely to suffer from inattention and insufficient cleaning more than where liberal working space is provided adjacent thereto, and rapid deterioration will continue until a condition is reached when the electrical equipment becomes hazardous to the attendant.

Sufficient space should be provided around all electrical equipment so that it will be readily accessible at all times. It is important always to keep the working spaces clear of accumulations of materials, and they should never be used for the storage of materials. Where ample space is provided and maintained, accidents are less likely to occur, and proper maintenance of the equipment is thereby encouraged.

Where there are no exposed live parts, no dimensions are given, as each case presents its own peculiar problem as to just how such space should be provided. If additions are likely or contemplated, it is advisable to take this into account and provide ample room.

Where there are exposed live parts on one side, definite minimum dimensions for the working spaces are warranted; where live or grounded parts are on both sides of the working space, greater space should be provided than where on only one side.

(c) **Clear spaces.**—It is an important matter to so design an installation that working spaces near live parts will not be used as passageways. This is intended to prevent short circuits by passers-by who may carry metal objects, and in addition men who are performing necessary work on or about such live parts will not be interfered with by passers-by.

(d) **Elevation of equipment.**—Owing to the reduced probability of persons coming accidentally in contact with exposed live parts where these are elevated considerably above the space ordinarily occupied by machine attendants, elevation of the live parts may usually be considered as at least equivalent to providing more liberal working spaces adjacent to live parts were they nearer to the floor line. For example, it is sometimes good practice to install motors above the heads of the machine attendants, so as to reduce the probability of accidental contacts, thus avoiding the necessity for inclosing the brushes and other live parts which would exist were the motors placed on a level with the workmen. In such cases the live parts may be more quickly accessible to qualified persons than if guards had to be removed.

306. Guarding or Isolating Live Parts.

(a) **Inclosure or elevation.**—The complete guarding of live parts when persons are near them would of course eliminate shocks and burns from electrical causes. With electrical-utilization equipment, suitable guarding is the more necessary, since the attention of the employee must be given to the processes and ordinary activities carried on in the given building rather than to the electrical machinery, which is only incidental or auxiliary. Wherever practicable, live parts should be so placed or guarded that only specially qualified electrical employees will have ready access. Frequently this is accomplished to some degree by placing motors or other equipment on the ceiling or under the floor and providing well-guarded starting and control devices convenient to the operator of the machine concerned. Individual-drive motors are often placed out of reach on top or underneath the machine driven. In some shops the handling of pipes or rods makes even a considerable elevation ineffective. Eight feet is named in the rule as about the greatest height to which the average person can reach with his hands without standing on a chair or other support. Live parts at a lower level, and sometimes at higher levels than 8 feet, should generally be guarded against contact by one of the methods outlined in the rule. Complete inclosures for otherwise exposed live parts usually provide the most satisfactory protection, since they prevent short circuits by tools or conducting material in the hands of workmen as well as shocks by direct contact. Where inclosures are not feasible, efficient barrier guards may be used.

(b) **Exception where mats and platforms are used.**—In some cases insulating platforms surrounding the live parts will prevent shocks to workmen in the vicinity, but they are less effective in preventing the almost equally dangerous short-circuits which frequently occur from accidental contact of tools or materials in the hands of workmen. Such platforms, if used, should be suitable for the conditions, and where dampness or oils are present many types of insulating platforms, especially of wood or other absorptive material, become relatively ineffective; and other forms of protection should be used. Much better standardizing of insulating mats and platforms than exists to-day should be brought about by development of suitable detailed requirements. It seems probable that rubber mats of sufficient thickness and properly prepared so as to be free from metal chips, or mineral filler, which would reduce their insulating value, would be very suitable either in damp or dry locations, if no oil, metal dust, or metal-chip accumulations are to be expected.

Where the materials handled include metal rods or pipes or other conducting materials, the insulating platforms, if used, would need to be of very considerable extent beyond the live parts in order to be effective, and it will thus be found that the field for use of insulating platforms or mats as a protection for workmen against shock from utilization equipment is very restricted and other more positive forms of guarding will usually be necessary. (Compare rule 304, (*c*).)

307. Hazardous Locations.

(a) When explosives and inflammables exist.—It is extremely important to provide proper explosion-proof equipment in rooms where explosives, gas, or explosive flyings exist. Frequent accidents have been due to explosions caused by arcing at opening of switches, or at brushes, where explosive dust was present. Cork, coal, and grain dust are especially hazardous. It often happens that hazardous processes are instituted in rooms where formerly no hazardous processes were carried on. The electrical equipment in such places should be changed to meet the changed hazardous conditions.

By placing the electrical equipment in a separate room or compartment and therefore isolated from the hazardous process, gas, or flyings, a fair degree of safety is obtained. In powder magazines it is common practice to also place the lighting units in a separate compartment, with a heavy glass barrier between so as to admit light to the magazine.

The Bureau of Mines has approved certain types of motors as explosion-proof and is prepared, upon request, to test other motors, and approve them if satisfactory. (See Technical Paper, No. 101, issued by the Bureau of Mines.)

The most common material used for inclosing conductors in hazardous locations is steel conduit. Steel is also commonly used for incasing motors and controllers.

308. Protection by Disconnection.

When electric utilization apparatus or the machinery driven by motors is undergoing repairs or maintenance work, it is necessary not only that current should be cut off, but that assurance should be given the worker that it will remain shut off until he is through his work. Every installation has one or more switches controlling the power supply or subdividing it. The switches should be so arranged that the disconnection of any part of the installation will not interfere with the use of other parts. This would mean that every motor should have a separate disconnecting switch in addition to its control apparatus, since the latter may require the attention of the maintenance man. Considerations of expense sometimes preclude this, in which case one disconnector may control a group of motors. In this case it is necessary that all of the motors be put out of operation while work is being done on any one of them or its controller.

In order that motors shall not be started by others while a workman is handling it or its connected apparatus, the disconnecting switch should be in sight of the motor. In lieu of this it is satisfactory to have the disconnecting means equipped for locking in the open position, since this will permit the workman to protect himself by locking the switch open and carrying the key. If the disconnecting switch is not of sufficient capacity to rupture the full-load current of the circuit, it should be marked with that information and should either be locked when in the closed position or remain inaccessible to unqualified persons. In this connection see rules 328, (*b*) and 329, (*l*).

Rule 309. Identification of Equipment.

(a) Safety by identification.—The ability to readily identify and trace the connection of equipment not only facilitates repairs but safeguards against the danger of handling live parts in the mistaken belief that they are disconnected.

Where open wiring is employed, maintaining the relative position of the conductors is one element of identification. It may be well to mention also that where conduit is run close to other pipes some establishments use a color or other code for distinguishing between the pipes for various services, including, of course, the electrical in this color code. A code for the identification of piping systems, A. E. S. C., A–13, is in preparation under the sponsorship of the American Society of Mechanical Engineers and the National Safety Council.

(b) Voltage and use.—As a safeguard the identification should at least be sufficient to indicate the voltage and the intended use of the equipment or connection concerned. It is particularly desirable that the fuses and automatic circuit breakers protecting any circuit should be labeled to show the destination and character of the circuit concerned. Where, as is usual, such fuses and automatic circuit breakers are grouped in a cabinet or on a panelboard, such identification often provides the principal means for tracing the connections of the installation.

Sec. 31. CONDUCTORS

310. Electrical Protection.

(a) **Fuses and circuit-breakers.**—In general all ungrounded conductors should be provided with fuses or automatic circuit-breakers to protect them from overloads. Neutral conductors are excepted because the blowing of a neutral fuse might give rise to unbalanced voltages and cause lamps to burn out at critical moments when they are most needed. Also persons working on the circuit may be in some cases exposed to double voltage. Grounding conductors also should never be interrupted by fuses, since the protection afforded depends upon a reliable ground connection at all times.

On three-wire circuits when there are only lamps or appliances on the circuit connected between the neutral and outside conductors it would be proper to provide a neutral of the same size as the outside wires. Since a grounded neutral wire is not fused, it would not be properly protected if smaller than the other wires. If, in addition to the lamps and devices mentioned above, there are also connected motors or other devices between the two outside wires, the neutral in this case may be smaller than the other wires. The National Electrical (Fire) Code should be consulted for details concerning the proper use of conductors.

(b) **Grounded conductors.**—It is necessary in order to assure protection to persons that the protective ground perform its functions properly. Continuity of the ground connection is therefore essential so long as the circuit is connected to its outside source on which any higher foreign voltage is possible by accidental contact, leakage, or induction. Any fuse if inserted in the grounded conductor between the source and point of attachment of ground conductor might cause the loss of the ground and therefore loss of protection. This arrangement is improper and not permitted by the rules. But it is permissible to insert an automatic circuit-breaker between the source and point of attachment of ground conductor if this circuit-breaker disconnects all conductors from the source simultaneously. Such an arrangement is sometimes desirable and justifiable, since it takes care of both personal and fire hazards by not only interrupting any current flow over the grounded conductor but also cutting off the circuit itself until the trouble is remedied.

There is no necessity for placing a fuse or automatic circuit-breaker in a grounded neutral because no excessive current flow to ground in case of an accidental ground on the circuit is possible on such a conductor as long as its protective ground is properly maintained and the other conductors of the circuit are properly protected. In case of an accidental ground on the neutral within the building in addition to the protective ground, it can be readily seen that there will be no excessive current flow because of no appreciable difference of potential between the two grounded points. In case of accidental grounds on either outside conductor the fuse in such conductor, by opening the circuit, will interrupt the excessive flow.

(c) **Switches.**—Switches should be constructed so that all poles of the circuit are simultaneously broken. Certain exceptions are permissible. Grounded conductors are not required to be interrupted by the switch. In the case of three-wire services it is sometimes desirable to open one of the outside conductors without opening the other, so as to permit renewing fuses without entirely interrupting service. Special devices are obtainable for accomplishing this result. The device is arranged so that the neutral can not be opened without opening both outside wires. Still another exception is desirable in the case of certain theft-proof service-entrance and meter devices. In order for these devices to be effective, it is necessary to connect the potential coils of the meter on the service side of the switch, and then the operation of the service switch does not disconnect the potential coils. Meter accuracy is also improved by having the potential coils always excited.

In two-wire branches single-pole switches are permissible, but on grounded circuits they should be placed in the ungrounded conductor. This results in leaving the utilization apparatus at earth potential when not being operated. The application of this rule causes a complication in the case of key sockets and receptacles of an old design in which the key interrupts the conductor to the screw shell. Rule 312 requires the grounded conductor to be connected to the screw shell of the socket, as illustrated in Figure 29. The key should break the connection to the center contact. Sockets which break the connection to the inner screw shell are not permitted on grounded circuits. Manufactures have discontinued the design which had the key in the conductor to the shell in favor of the design having the key in the conductor to the center contact, or the design which breaks both sides of the circuit.

311. Protective Covering.

(a) **Mechanical protection.**—There are numerous ways of guarding conductors on side walls from mechanical injury. Two of these methods are shown in Figure 28. The use of conduit as illustrated gives a very substantial construction and is even better than the use of the wooden boxing, which itself is likely to be broken by heavy pieces of material or hard blows.

In basements, cellars, attics, and other places where horizontal runs of conductors are liable to mechanical injury, protection should be provided, as also indicated in Figure 28.

The above situations are a few of those in which it is desirable to provide protection. There are many others that may require protection. Meter loops in open wiring should

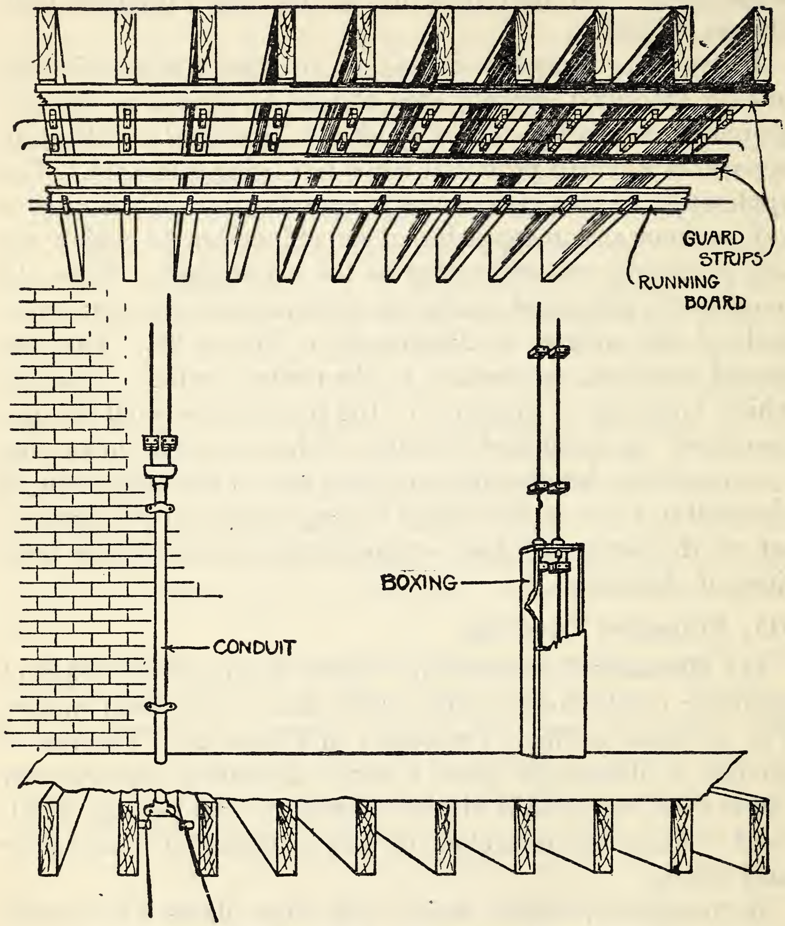

FIG. 28.—*Mechanical protection of conductors*

be supported on proper insulators, such as knobs or cleats. If this point is not given attention, hazardous conditions may develop in the course of additions to the system or due to frequent testing and removal of meters.

There are many special meter-protective devices on the market intended for the inclosure of meters and their wiring. Such inclosure of meter and wiring makes not only a safe job, but provides for easy testing and also prevents theft of current.

There are certain situations which demand an insulating covering of a fireproof nature where rubber-covered conductors should not be used. Where wires are closely grouped behind switchboards, rubber-covered wire would be a fire hazard, and therefore a type of wire known as slow-burning should be used. Also, in extremely hot places this type of wire will endure when other insulations, such as rubber, would soon deteriorate.

(b) **Bare conductors.**—There are certain places where it is permissible to install bare conductors. Usually these bare conductors are in the form of rigid busbars and they are generally isolated; therefore the likelihood of a short-circuit is small. Grounded conductors should be kept insulated from ground everywhere except where the actual ground connection is made, because differences of potential along the conductor would give rise to stray current if they were in contact with ground at more than one point.

312. Identification of Conductors and Terminals.

There are numerous ways of complying with this rule. The ideal method is to use a conductor whose insulation is distinctive by its color throughout the entire installation; such as a conductor having a white insulating covering. A colored thread or number of threads interwoven in the outer braid would be an identification. A conductor having a

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core of distinctive coloring would probably be a sufficient means of identification. Still another method is to tag the conductor at each terminal with a substantial tag or a band of metallic ribbon which can not easily be lost. For rubber-covered conductors not larger than No. 8 the recognized method is a white or natural gray covering.

The marked conductor should always be the grounded conductor, and where single-pole switches are used they should be inserted in the ungrounded side of the circuit, which, of course, will be the unmarked conductor. But in sockets the grounded side should be connected to the screw shell. (See fig. 29.) This is because contact is more liable to be made with the inner screw shell than with the center contact. Such contact may occur when a lamp is partly screwed in, the fingers being against the base of the lamp. If the fingers are inserted in a socket or receptacle, this contact is most likely and occurs frequently when children handle floor or baseboard receptacles. Moreover, insulation breakdown or metallic objects are likely to connect the grounded outer shell with the inner screw shell and cause fire hazard unless the shell is properly polarized.

For safety reasons standard sockets have the switch in the connection to the center contact, as discussed under rule 310, (c).

Where it is necessary to carry two conductors between the lighting outlet or appliance controlled and a single-pole switch, if these conductors are manufactured assembled, one of these conductors may be marked by a white braid, although the switch is by requirement placed in the unidentified conductor. This can be obviated by running the circuit conductors first to the switch and then to the fixture outlet.

(b) **Terminals.**—Where it is feasible to maintain the polarity of a wiring system through portable and utilization devices, it is advisable to do this. Where an extra conductor for the purpose of protective grounding accompanies circuit conductors, this protective grounding conductor and termi-

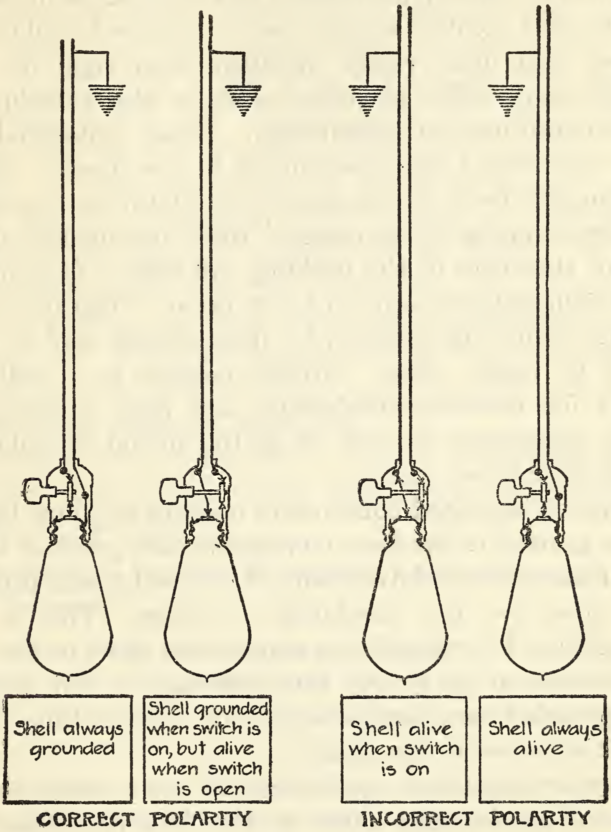

FIG. 29.—*Connection to key socket with respect to polarity of inner screw shell*

nals to which it is to be attached are to be identified by a means distinctly different from that used to identify the grounded circuit wire. This is becoming common in portable cords for industrial use.

313. Guarding and Isolating Conductors.

There are numerous kinds of conduit or duct for inclosing conductors. Rigid steel conduit is the most extensively used, since it makes a permanent and substantial installation. Flexible steel conduit is also used. Armored cable is much in favor and more easily installed than rigid or flexible conduit; nonmetallic sheathed cable is also suitable under certain conditions of installation. Many industrial plants find it convenient and economical to use fiber or tile duct laid beneath floors where heavy conductors are concerned. Sometimes special ducts integral with the concrete or other fireproof structure of the building are used. In some cases special iron gutters seem to be in favor. The use of wood molding should, in general, be discouraged, and it is prohibited in many cities. Metal molding is a well-known product for incasing conductors and finds application in making extensions as well as in the initial installation in existing structures.

Wherever insulated conductors operate at more than 300 volts to ground it has been considered safe practice to place them at least 8 feet above floors, if no mechanical protection is provided for the insulating covering. This is easily accomplished by running the conductors close to the ceiling or otherwise so as to get the necessary 8 feet clearance. For unguarded bare conductors of any voltage this clearance of 8 feet is necessary for safety.

Wherever insulated conductors of more than 300 volts to ground are brought closer to the floor line than 8 feet, they are required to be placed in conduit or otherwise to be guarded by screens or other inclosures. Bare conductors of any voltage in such locations are required to be guarded. It is usually desirable to inclose all conductors regardless of their elevation. The inclosures mentioned above are the most generally used. Such inclosures protect conductors from accidental short circuits, besides protecting persons from shock, and also in some cases prevent communication of fire from the insulation to surrounding materials or objects.

314. Guarding in Damp or Hazardous Locations.

(a) **Support of conductors in damp locations.**—Conductors in very damp locations where moisture collects on the wires can not be considered as effectively guarded by their insulating covering, even at low voltages, since the deterioration of insulation and the danger from even slight leakage is considerable. If such conductors are not in grounded conduits, the only effective protection would be through isolation by elevation beyond reach of persons in the vicinity. In order that the surfaces on which the conductors are supported will not receive sufficient leakage to become dangerous to persons in the vicinity, the open wires in such locations should be supported on insulators having a leakage path of sufficient length to make leakage negligible.

(b) **Conduit for conductors in hazardous locations.**—For conductors in locations where inflammable gas exists see discussion of rule 154.

315. Precautions against Excessive Inductance and Eddy Currents.

With commercial frequencies of 25 to 150 cycles, large reactive drop of voltage would occur on conductors run singly in iron or steel conduits, owing to their high magnetic permeability. There would also be heating of the conduit by the induced eddy currents which in turn would overheat the conductor and cause deterioration of the insulation. Moreover, the extra inductance in the circuit would cause fuses to blow more violently than otherwise. Therefore, both conductors of the circuit should be run in the same conduit. (See fig. 30.)

While this rule does not prohibit the running of the grounding conductor in conduit, the above reasons seem to point out the desirability of nonmagnetic casings. Should occasion ever arise for this conductor to discharge any large rush of current, there would be present a considerable reactive drop of potential between the circuit and the ground, higher than if the conduit were omitted. Therefore, the iron or steel conduit through which a grounding conductor is run may tend to defeat the purpose of the ground connection unless there is an electrical connection between the conduit and the inclosed grounding wire at each end of the conduit. In general, casings of nonmagnetic material should be used. Wood molding has been adopted in some cities.

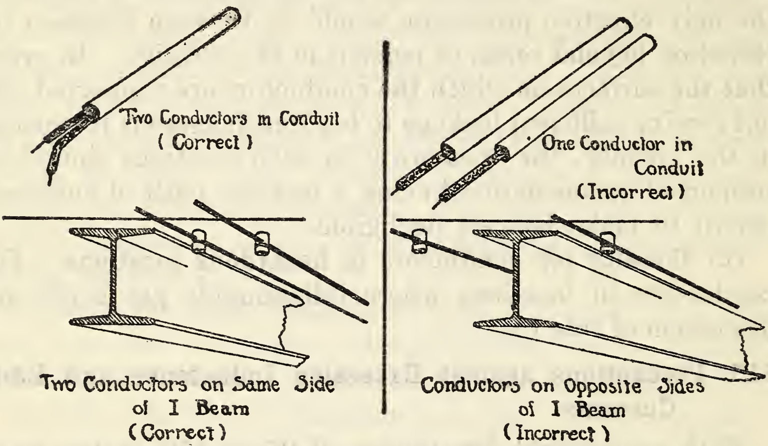

FIG. 30.—*Method of running conductors to prevent eddy currents*

It is particularly undesirable to run grounding conductors for lightning arresters in conduit unless the conductors are electrically connected to both ends of the conduit. If the lightning-arrester ground is of high resistance this has the disadvantage of making the potential of the conduit considerable during heavy discharges or when any defect makes a continuous leakage to ground. Where the ground connection is likely to be of high resistance, only nonmagnetic material should be used for enclosures about the grounding conductor, and if of metal the insulating covering of the conductors should be kept intact.

316. Taping Ends and Joints.

It is essential to properly tape joints in insulated conductors or otherwise cover them with insulating materials. Ends should also be properly taped. The taping should be equivalent to the insulation of the conductor itself. For rubber-

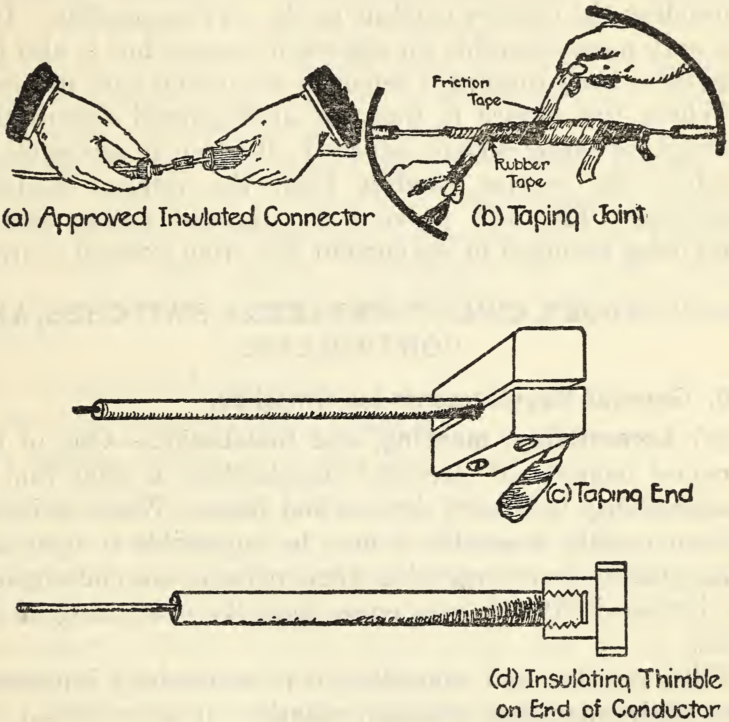

FIG. 31.—*Protection of joints and ends of wires*

covered conductors layers of rubber tape should first be applied, followed by layers of friction tape. It is well to paint the taped portions with an insulating paint or varnish. For ends of insulated conductors used as bus bars on switchboards, thimbles of glass, porcelain, or other insulating material made especially for this purpose are often used. (See fig. 31.)

The American Society for Testing Materials has formulated a specification for friction tape.

317. Grounding or Isolating Service and Interior Conduits.

The ground for interior conduit where electrically continuous with the service conduit is best effected by directly grounding the interior conduit to the service conduit. It is not only more desirable for electrical reasons but is also less expensive than running a separate grounding wire for each.

Where the service is from an underground distribution network of large current capacity, it often is advisable to insulate the service conduit from the interior metallic sheathing. This will prevent the interior wiring system from being involved in the current flow from exterior sources.

Sec. 32. FUSES, CIRCUIT-BREAKERS, SWITCHES, AND CONTROLLERS

320. General Requirements for Switches.

(a) **Accessibility, marking, and installation.**—One of the personal hazards of electrical installations is that due to inaccessibility of control devices and fuses. Where switches are not readily accessible it may be impossible to open circuits quickly in emergencies when persons are endangered; the inaccessibility of fuses encourages the overfusing of circuits.

With switches and controllers it is particularly important that their operating position, whether open or closed, be clearly indicated, both to prevent handling of live-circuit wiring and devices in the mistaken belief that they are dead, and to avoid the closing of switches when starting would be dangerous.

It is usually practicable to install single-throw knife switches to open downward. Double-throw switches can be provided with stop blocks on one or both sides, and latches are sometimes used to prevent the switch being closed by gravity. Frequently they can be mounted to advantage with the throw horizontal.

(b) Switches for special circuits.—There are certain types of switches which should be kept under lock and key, as the safety of many persons is dependent upon the functioning of the devices or lighting controlled by these switches. They may be placed in special locked cabinets or they may be located in a special booth or room accessible to qualified persons and excluding other persons.

(c) Exit lights.—Since the safety of large numbers of persons is concerned in the proper maintenance and operation of exit lights normally kept lighted in halls and theaters, they should have proper attendance, and their control switches should be placed in the lobby or front part of the theater.

321. Hazardous Locations.

See discussion of rules 113 and 307.

322. Where Switches are Required.

(a) Service switches.—For every electrical utilization installation, whether it be in an industrial plant, dwelling, business house, or any other type of occupancy, the presence of a main switch enables the supply to be cut off in an emergency. Dark corners, inaccessible and damp places should be avoided whenever possible in locating the main or service switch. In selecting the location due regard should be given to the possibility of firemen or others being able to quickly locate the service switch in case of a fire. Since the service switch and meter are usually near to each other, accessibility is important also from the meter reader's point of view.

Modern service switches are mounted in metal inclosures, and may be opened or closed by external handles without opening the inclosure, and are so arranged that the fuses are automatically disconnected before they can be touched. If the branch circuits can all be controlled by individual switches that may be operated without exposing live parts, the mandatory requirement for external operation of the service switch is waived.

(b) **Circuit switches.**—Every device using current should be provided with a switch, thus enabling the device to be cut off from the source of current in case of an emergency. Each large device and each group of small devices should have a separate switch, so as to avoid cutting out of service any unnecessarily large number of devices at a time.

(d) **Fuses.**—See discussion of rule 324, (*b*).

323. Character of Switches and Disconnectors.

(a) **Interrupting capacity of switches.**—A frequent cause of accidents has been the attempt to interrupt large currents by switches incapable of safely breaking the circuits. While the presence of trained operators and the use of ammeters in stations may offer a considerable degree of protection against the dangerous opening of switches under severe overloads, no such safeguards are, as a rule, feasible with utilization equipment. The switch must therefore be proportioned to the maximum current it may be expected to break, and this will ordinarily be limited only by automatic cut-outs (usually fuses) in circuit with the switch. All automatic cut-outs have a time lag, however, and even where capable of protecting the switch under ordinary circumstances may permit instantaneous currents, such as occur with the starting of motors too large for the safe operation of the switch. Opening the switch at this time is, of course, unlikely, and could by issuance of proper warnings be prohibited readily, even with nonelectrical employees. (See discussion of rule 164.)

(b) **Capacity of disconnectors and warning signs.**—In utilization installations the disconnectors would usually be made accessible only to qualified persons by placing them in a separate room, but where this is impracticable they may be inclosed and placed under lock and key. Danger signs should be used on disconnectors to warn against opening under excessive load.

(c) **Locking or blocking.**—Inclosed externally operated switches are provided with locking arrangement. Locking is especially desirable and important on motor-starting switches to prevent accidental starting and injury to anyone working on the motor or the machinery it drives. Numerous fatal accidents have resulted from workmen being thus caught in machinery.

(d) **Good contact.**—Small switches, and even single-pole switches of large capacity, sometimes cause burns due to arcing at the contacts near the hand of the operator on failure to close properly. Good alignment will, of course, avoid this trouble.

Poor contacts may start fires by heating, sufficient heat being conducted through copper switch connections to inflammable conductor coverings.

(e) **Inclosure of switches.**—See discussion of rule 328.

324. Disconnection of Fuses and Thermal Cut-outs Before Handling.

(a) **Automatic disconnection.**—There are now numerous devices available which are so arranged as to accomplish the purpose of this rule; namely, to render fuses dead when they are exposed for renewal. These devices usually consist of a combined switch and fuse, although types have been designed which provide for the fuse being removed from the fuse holder by the opening of the cabinet.

Inclosed fused switches range in type from those merely providing a switch handle exterior to the case to those providing, in addition, that parts normally carrying current are never exposed to contact while alive, even though the terminals for connecting line and load are interchanged. The gradations from one type to the other are too numerous to mention here.

Since the fuses must be so arranged that they are necessarily disconnected before they can be touched, an arrangement involving a complete interlock is necessary to meet the requirements of this rule for voltages exceeding 150 volts to ground. A partial interlock which requires a switch to be opened before the case can be opened but permits the switch to be closed without first closing the case would not meet the requirement; since the case could be left open or ajar with the switch closed and the fuses could then be touched by any newcomer without first disconnecting them from the source of energy. In other words, it is necessary to have a construction in which the fuses are accessible only while disconnected from the circuit.

However, it is not intended that the rule should bar out interlocking types of fused switches in which it is possible to defeat the interlocking mechanism after having opened the case by manipulating it by a screw driver or other means, even though such a deliberate and intentional action might permit the closing of the switch while the fuses are still accessible and the consequent leaving of the switch in the closed position without automatic disconnection of the fuses before they can be again touched.

When fused switches of the type not interlocked are employed, it is found that operators frequently fail to close the door of the case after it has been opened. This results in leaving live parts partially exposed which, of course, is an undesirable condition. The use of a fused switch containing the interlocking feature is desirable as a means of assuring that cases shall normally be left closed, aside from the protection which it affords the person renewing the fuses.

Even for utilization installations of less than 150 volts to ground, it is desirable to provide the interlocking type of switch in order to afford greater protection.

Where switches and fuses are mounted on switchboards and panel boards, it was common in former years to find the live parts exposed. Practice has more and more tended, however, toward the use of dead-front boards, and the automatic disconnecting features can be incorporated in this type of construction.

(b) **Switch ahead of the fuse.**—Where automatic disconnection of fuses is not provided, there should at least be an opportunity for making the fuses dead before handling, and this is accomplished by placing the switch ahead of the fuse. This applies to all voltages; exception is made only for service and meter switches, which will not be accessible to unqualified persons, because in the older types of these it was found convenient and was quite customary to place the fuse ahead of the switch. In the more modern types this is not the case.

(c) **Live load.**—This paragraph deals with a special case coming under the more general rule but provides an alternative form of installation. Storage batteries which are charged at a voltage exceeding 150 volts are extremely rare, most high-voltage batteries being subdivided for charging separately or with sections in parallel. Such charging as may be done at higher voltages will usually occur in stations, and consequently the rules of part 3 will not be applicable. For cases coming under this rule the type of fused switch which breaks the circuit on both sides of the fuses is applicable, but as an alternative it is acceptable to use a supplementary switch to break the circuit on one side of the fuse, since there is little likelihood that such a switch will be left closed during replacement of fuses.

325. Arcing or Suddenly Moving Parts.

(a) **Location.**—The location of fuses and circuit breakers away from passageways, working spaces, and places where passers-by may be burned is one element which contributes toward reasonable safety. As an instance of nonobservance of this safety measure the presence of circuit breakers approximately 6 feet above the floor of some car platforms looms up prominently.

(b) **Suddenly moving parts.**—The same reasons apply for properly isolating circuit breakers having moving parts sufficiently heavy to cause injury.

326. Grounding Noncurrent-Carrying Metal Parts.

It is intended that the important exposed metallic parts of switches be grounded, such as the frame or case of an oil switch. It is understood that very small isolated metal parts, such as screws, cotter and other pins, which are not liable to become alive, are not included. This especially applies where the ground connection required would be more prominent than the detailed parts.

327. Guarding Live Parts.

(a) **Guard disks and handles.**—The open switch while ordinarily undesirable, is still permissible on circuits up to 150 volts to ground, but wherever the switches are fused above 60 amperes, guard disks or other shields placed on the handles must be provided to protect the operator from burns and from contact with live parts. For complete protection it would be desirable to inclose switches as outlined below even for voltages of less than 150, particularly for the larger current capacities.

(b) **Inclosure.**—On voltages of more than 150 to ground the hazard is greater, and all switches where otherwise accessible to ordinary persons must be inclosed in cabinets so designed as to permit the switch to be operated from the outside without opening the cabinet, and thereby exposing the person to live parts within. Numerous forms of externally operated switches are available and in general use.

(c) **Platforms and mats.**—When, however, switches of more than 150 volts to ground are accessible only to a qualified operator and others are excluded, they need not be arranged with operating handle on the outside but may be placed in ordinary locked cabinets. At the same time any conducting floors should be provided with insulating platforms or mats. The possibility of shock to the qualified operator is remote in this case, and in addition he is more qualified to guard himself against any hazard than is the ordinary person.

(d) **Blades dead.**—The arrangement of knife switches and their connections to circuits involves features which should at the outset be given consideration by the manufacturer as well as by the installer. In the first place, the most safe arrangement would necessitate the blades being hinged at the fuses. In the second place, with the blades hinged at the fuses, they should be connected so that the blades are dead when the switch is open. That is a matter to be taken care of by the installer, and it should be insisted upon by the inspector. No more material or labor is necessary to accomplish this, but greater safety is obtained because when the switch is open the blades and fuses are dead, and the only live parts are the jaws of the switch. Of course, this arrangement is not possible with double-throw switches where the source of supply must be connected to the middle points; but the blades, if not the fuses, will be dead when the arrangement is for throwing a motor or lighting circuit upon either of two sources of supply. In motor-starting switches the fuses are frequently put on the line side of the switch, but here it is preferable to arrange the connections so that the fuses are dead with the switch open, and to protect the live blades by guards.

328. Inclosed Air-Break Switches (not including Snap Switches).

(a) **Locks for switches.**—It is generally important from a safety standpoint to be able to lock switches in the "off" position. The unexpected closing of any circuit should be avoided, and this is especially true during repair or maintenance operations on the circuits or devices controlled by the switch. It is generally undesirable to be able to lock the switch in the closed or running position. Only for disconnecting switches and in the case of circuits, the opening of which during operation will introduce a special hazard, will provision for locking them in the "closed" or "running" position be justifiable. Even in the latter case it is preferable to prevent unexpected opening of the circuit by locking extrance to the room containing the switch rather than by locking the switch.

(b) **Locks for disconnectors.**—Disconnectors are especially useful to maintain separation between a circuit and a source of electrical supply. The same reasons for provision for locking switches in the open position apply to disconnectors with greater emphasis. The design of disconnectors is usually such that they are not competent to break the current and open the circuit under load. An attempt to open disconnectors under conditions of load on the circuit may involve a disastrous arc and personal injury, especially eye injury to those near by. To prevent an attempt to open disconnectors under load through error or inadvertence, it is desirable to be able to lock them closed.

Disconnectors may tend to open themselves under heavy short-circuit currents due to magnetic forces. They are, therefore, preferably provided with snap catches to prevent this.

(c) **Marking.**—It is necessary for switches to carry markings including all information necessary to insure their safe installation, including the name of the maker to authenticate this information. The ampere and voltage ratings are necessary to insure the switch against installation to control a circuit it can not safely open under load. The open or closed position of the switch should be evident, and this may be secured by marking the handle positions. When the design of the switch makes it necessary to distinguish between the "line" and "load" terminals to secure safe installation, so as to insure that the blades will be dead when the switch is open or the fuses accompanying the switch will be dead when exposed, etc., it will be necessary to mark the terminals "line" or "load."

Switches for special uses may require additional information concerning their installation or functioning than is specified in the rule.

(d) **Operating handle.**—Switches should be opened or closed with a sure, unfaltering motion to their final position. Since it is impossible to see the exact position of the switch blades when inclosed, substantial limit stops should be provided for the motion of the handle, so that when the handle is brought against these stops the switch blades will either be snugly in the closing jaws or safely open.

(e) **Grounding.**—To insure the safety of persons near the switch case or operating the switch by a metal handle, these must be effectively grounded. It is found by experience that a metal handle operating in grounded metal bearings will be safely grounded through its bearings.

329. Control Equipment.

a) **Classes of inclosures.**—In order that inclosures may be sufficiently substantial, dust tight, live parts guarded, etc., for the various situations in which they will be installed, standards for three general classes of inclosures are established.

(c) **Clearances.**—To insure that the metal inclosure, although required to be grounded, will not become alive or short-circuit the live parts within, general standards for internal clearances and barriers are specified, recognizing that in specific instances test demonstrations may justify a modification of these standards.

(d) **Securing covers, etc.**—To insure the integrity of the inclosure and the continuity of its protection, parts of the inclosure that might otherwise easily become separated from the device should be secured to it.

(e) **Inclosures for floor-mounted controllers.**—When no hazard of inadvertent contact with bare parts is introduced by the omission of part of the inclosure, such as at the top when more than 6 feet above the floor, or the bottom when within 6 inches of the floor, and also when no hazard from the surrounding conditions of the installation will be involved, parts of the inclosure may be omitted.

(f) **Marking.**—To insure that controllers will not be installed in circuits for which they are not designed or that they will not be installed wrongly or expected to function differently than intended, they should carry adequate markings and ratings, including a wiring diagram that may be separate from the controller.

(g) **Wiring diagram.**—See paragraph (*f*).

(h) **Overload protection.**—It is generally advisable to include overload protection, which is required for all devices, as a part of the controller. If, however, overload protection is not incorporated in the controller. it will then need to be provided as a separate unit.

(i) **Under or low-voltage protection.**—Without low-voltage protection the restoration of voltage after some temporary service failure will involve the hazard of unexpected starting. Therefore, unless the motor and the driven machinery are isolated and accessible only to qualified persons, low-voltage protection must be incorporated in the controller.

Large motors generally require a definite starting sequence to limit the current. Without low-voltage protection a temporary failure of the electrical supply service might involve excessive currents on its restoration, damaging the equipment.

(j) **Installation of controllers.**—It is advisable to inclose, guard, or isolate all controllers of all voltages. Controllers on circuits limited to less than 150 volts to ground may, however, include exposed live parts. The live parts, however, shall be so arranged that the operator will be very unlikely to come in contact with them when operating the controller or be burned or flashed by arc-rupturing parts.

(k) **Remote-control apparatus.**—Contactors, relays, resisors, etc., of remote-control apparatus should be accessible for inspection and maintenance but isolated from unqualified persons or inclosed.

For voltages exceeding 150 isolation is to be preferred to grounding metallic inclosures, both because it promotes accessibility of the parts to qualified persons and usually does not involve extensive grounded surfaces near to live parts. Qualified persons approaching live parts of remote-control apparatus should be protected by insulating floors or mats.

(l) **Lock for control in "off" position.**—See discussion of rule 328, (*a*).

Sec. 33. SWITCHBOARDS AND PANEL BOARDS

330. Accessibility and Convenient Attendance.

(a) **Control arrangement.**—The accessibility of all switches on a switchboard is an important matter which should be given attention in the design of the board as well as in its installation. Crowding instruments and switches is not good practice, because it causes confusion and inability to readily identify the proper switches in an emergency.

(b) **Location of instruments.**—Frequently it becomes necessary to place additional instruments or devices on a board after the initial installation. This may result in a crowded condition. Boards should be designed with ample space, and they should be so placed that future additions will not crowd the working spaces.

331. Location and Illumination.

It is usually quite feasible to place switchboards well away from machinery of all kinds, but in cases where boards must be placed in rooms crowded with machinery the partitioning of adequate switchbaord space, by means of a substantial guardrail, affords the much-needed protection to the switchboard itself, as well as to the operator.

In installing the board a location should be selected not likely to be blocked by future alterations or storage of materials. Locations where bars of metal or other heavy objects are handled should be avoided as much as possible to avoid short circuits or mechanical injury.

332. Arrangement and Identification.

The wiring behind switchboards sometimes becomes very complicated. It is a very good plan to keep the conductors separated as much as possible, so that they can be readily identified and repairs easily made.

333. Spacings, Barriers, and Covers.

(a) **Separation of bare parts.**—It is intended by this rule to eliminate as many unnecessarily exposed current-carrying parts as possible.

It is desirable and necessary at times to provide, for certain types of boards, barriers which will prevent accidental short-circuiting. On certain types of boards installed in special locations such guarding would especially be required.

(b) **Portable covers or shields.**—This rule is intended to cover switchboards where the hazard to workmen is very pronounced. It is customary on large switchboards of this kind for the management of the plant to furnish the necessary safety devices in the form of rubber shields or other types of barriers or coverings to sufficiently protect workmen when it is absolutely necessary to work on boards while alive. Rubber sheets or mats are very effective and useful when placed over live parts. The rule also conveys the idea that men should take the necessary precautions when working around parts liable to be short-circuited.

335. Guarding Current-Carrying Parts.

(a) (b) **Inclosure.**—Switchboards are generally of sufficient size to warrant providing a separate space for them which need be accessible only to a few qualified persons. If space is very restricted, cabinets may be used which can be opened readily for switchboard operation, or the switches may be arranged for operation without the necessity of opening the cabinet, thus permitting the absence of protecting guards except during the comparatively infrequent repairs on the switchboard.

Remote control, of course, provides entire safety to the operator and is advisable for the higher-voltage circuits and large current capacities when circumstances permit.

Complete insulating floors without rough or broken edges have few of the disadvantages of unevenness and unreliability which mats and platforms possess, and in the dry, clean surroundings usual about switchboards afford effective protection to the operator touching only one live part. Various insulating materials, such as alberene stone, soapstone, slate, and marble are satisfactory if they have no conducting veins, and are maintained so as not to become slippery. Specially prepared materials having antislip surfaces are also available. Where insulating mats or platforms are used, it may be advisable to set them in a depressed section of the floor with the edges of the mats or platforms made flush with the surrounding floor surfaces.

Switchboards generally control the larger equipments, and for this and other reasons it becomes important to provide for very quick access, and often it is advantageous to make all current-carrying parts entirely open to inspection or quick repair if accessible only to qualified attendants.

A summary of replies from manufacturers of switchboards is to the following effect:

Within reasonable limits it is desirable to restrict installation of switchboards of all voltages to spaces accessible only to qualified persons, both on account of hazards from exposed live parts and also to protect against malicious or careless interference. No consideration seems to warrant having switchboards placed where they would be accessible to the general public or to factory employees engaged in other work.

Panel boards may be made entirely inaccessible to the general public or employees in general by location in separate rooms, as required for switchboards, or since rapid repair is usually not so necessary a consideration as with the larger switchboards, by inclosure of the panel boards in locked cabinets. Panel boards, however, usually control smaller devices than do switchboards, and considerations thus often exist which warrant the accessibility of panel-board switches to the occupants of the rooms where the panel boards are installed. They can then be arranged by use of "dead-face" panels so that live parts are inaccessible to unqualified persons, the fuses, buses, and terminals being inclosed in locked compartments.

(c) **Plug-type boards.**—The hazard of the frequently used bayonet type of plug connector used with constant-current switchboards is usually recognized by the operator, and he tries to be careful in its use. The worst condition arising is that when the rod is withdrawn from the inner contact it still touches the outer contact, so that a considerable portion of the exposed bare rod is alive. This hazard is being eliminated in some instances by the use of insulating cylindrical shields fitting over the device, so that the rod will be covered with insulation until it leaves the outer contact.

In some theater switchboards the distance of both contacts behind the board is such that no live part of the plug is ever exposed at the front.

Transfer cables always constitute a danger and are undesirable for use of other than qualified persons. They may be left with one side connected and the other hanging or lying on the floor. During handling, cables may break down and persons may be injured by shock or burn from the conductors within.

(d) **Dead-front boards.**—"Dead-face" panel boards have been much used abroad, and their use has recently become extensive in this country. For theater-stage switchboards, however, with the attendant panic hazards and the necessity for very quick changes, the careful inspection for years by underwriters and municipal authorities alike have caused a marked progress toward elimination of exposed current-carrying parts. The city of New York affords probably the best examples in the country of "dead-face" theater-switchboard installation, many of its theaters being exclusively equipped in this manner, thus providing correspondingly greater safety to their switchboard operators, players, and audiences. Dead-front boards are now required by the fire underwriters and by most cities.

It is not feasible to bar out other forms of boards already in use, but where installed they must be isolated or guarded. They should not be permitted for new installations.

337. Panel Boards.

(a) **Arrangement of equipment.**—The arrangement of plug fuses on panel boards, so that the shell of the receptacle is connected to the load side of the wiring, promotes the guarding of live parts, since when both fuses are screwed out the only live parts exposed by so doing are the center contacts.

(c) **Marking.**—As in the case of all other separate electrical devices, such as switches, controllers, motors, etc., a marking to identify the circuit conditions under which the panel board is designed to function safely must be an integral part of the device.

(d) **Protection against moisture.**—It is never advisable to locate panel boards where exposed to moisture. Such conditions greatly increase the liability of failure of the device, especially its insulation, and increase the hazard to persons operating the panel board. If, however, it is impracticable to locate panel boards in permanently dry locations, weatherproof cabinets should be used.

(e) **Hazardous locations.**—Panel boards must not be located where the presence of inflammable gas or dust may involve an explosion hazard. Panel boards may be separated from atmospheres occasionally charged with inflammable gas or dust by locating them in separate rooms well ventilated to outside clean air.

(f) **Residences.**—In residences exposed live parts should be especially avoided because of the possible access of small children to them. The importance of installing in residences panel boards with no exposed live parts, even when the cabinet door is open to operate switches or when fuses are being changed, is strongly emphasized.

In case, however, live parts are guarded only by the closed cabinet door, they should be not less than 4 feet above the floor to limit the liability of bringing moving objects into inadvertent contact with them and to put them out of easy reach of small children.

Sec. 34. MOTORS AND MOTOR-DRIVEN MACHINERY

340. Control Devices.

(a) **Speed limitation.**—The importance of automatic speed-limiting devices for use with certain types of motors and converters can not be overemphasized. Centrifugal devices are generally used, which open or close circuits and operate relays actuating switches in the motor-supply circuits. Motor generators and rotary converters when operated in parallel with other direct-current generators are likely to attain high speeds upon the interruption of the alternating-current supply, due to the reversal of the current in the series field winding and the consequent weakening of the field under motor action. The characteristics of series motors are also such as to cause them to run at excessively high speeds under light or no-load conditions. Separately excited motors are particularly liable to "run away," since the circuit supplying their excitation may be interrupted while the armature current is maintained. Direct-connected fans, pumps, or loads of the same character driven through positive mechanical connections, such as are provided by gear or chain drive, obviate the necessity for speed-limiting devices. Belt drives are not free from the danger of releasing the motor.

(b) **Adjustable-speed motors.**—Frequently motors are provided with field rheostats capable of weakening the field dangerously. The danger of overspeed with excessive resistance in the field circuit may be serious when starting the motor without load.

(d) **Under or low-voltage protection.**—The automatic return of motor starters to the "off" position when energy supply fails (or is cut off by throwing of switch) will prevent severe mechanical strain to the motor and connected machinery and also prevent the operation of low-voltage releases on equipment controlling other circuits, which is likely to occur if full voltage, without the resistance or reactance of the starter, is thrown on a motor at rest. Also, in the case of a. c. starting switches when no resistance is used in starting, low-voltage protection is essential to protect the motor from unexpected starting.

341. Hazardous Locations.

See discussion of rules 304 (*c*) and 307.

342. Deteriorating Agencies.

(a) **Inclosures.**—An example of the application of this rule is the case of a driving motor installed under the tub of a washing machine. This motor may be subject to splash of soapy water from the tubs. It should, accordingly, be roofed over in such a way as to protect it.

(b) **Grounding frames.**—The frame of the washing-machine motor cited above should be grounded. If this motor were within a housing, grounded, if metallic, so that its frame could not be touched without removing the housing, it would be permissible under rule 304 (*c*) to leave the frame ungrounded and effectively insulate the motor by mounting it on insulating supports and connecting it to the driven machinery by an insulating joint in the shafting.

343. Guards for Live Parts.

In some cases insulating screens or covers will be necessary about the exposed grounded parts rather than about live parts, where necessity for frequent adjustment of brushes, commutators, or other live parts not likely to be touched inadvertently makes guarding of such parts difficult. Fortunately, with modern motors such adjustments should be rarely needed, and it becomes simpler, where adjustments are needed and permanent guards for live parts are not feasible, to inclose the motor in a fenced space accessible only to qualified inspectors or repairmen. The less rigid rules for stations then apply to such motor installation. (See rules 121 and 124.)

For low-voltage machines guarding is sometimes obviated by use of insulating mats. These prevent the most frequent cause of shock—contact with electrical circuits while standing on grounded surfaces. The somewhat less frequent cause of shocks, touching electrical circuits while in contact with grounded surfaces but not by standing on them, can best be prevented by use of suitable inclosing or barrier guards about the live parts themselves. With motors of utilization equipment this protection should generally be provided wherever dampness or congested space or dangerous processes make insulating mats ineffective. With motors of utilization equipment of the higher voltages this precaution should generally be taken in relatively dry and clear spaces.

344. Grounding Machine Frames.

See discussion of rule 304 (*c*).

345. Protecting Moving Parts.

The protection of moving parts of machinery of all kinds is now the subject of many laws and orders of State industrial commissions. The standards of the casualty underwriters and the Safety Code for Mechanical Power Transmission, AESC, B 15, also apply in many installations. Since other influences are tending to standardize this subject the electrical safety rules simply require the provision of suitable guards, leaving detailed requirements to the authorities having jurisiction.

Sec. 35. ELECTRIC FURNACES, STORAGE BATTERIES, TRANSFORMERS, AND LIGHTNING ARRESTERS

350. Protection from Burns.

(a) **Inclosure of glowing parts.**—To prevent curious or unauthorized persons from injury by trespassing, or by gazing at the intense light, it is usually necessary to place the processes in a separate room or inclosure, to which no one is admitted without special permits.

(b) **Screens, hoods, goggles.**—The shielding of the eyes and unclothed body surfaces from the intense radiant energy of any electric furnace or welding process is quite essential, and this is usually recognized, although in the past too often only after severe burns and eye injury have been experienced by some employee. The action of an intense arc is to produce burns similar to those caused by the sun, but usually much more severe by reason of the close proximity of the arc. Much has been done by individual firms toward the development of special glass to protect the eyes, and it is not infrequent that a combination of glasses is used, some to cut down the intensity and others to exclude the ultra-violet and infra-red rays. The use of a helmet or similar headgear other than goggles is necessary to protect the face of those directly exposed to the arc. This often consists of a nonmetallic covering fitting over the head, with openings in front of the eyes fitted with glass, as above described. Some provision is also made for ventilation.

For welding, shields are sometimes provided instead of helmets. The shield is made to be held in one hand and can only be used in such operations as are possible without the use of both hands. For further details the National Safety Code for Protection of the Heads and Eyes of Industrial Workers (Handbook No. 2 of the Bureau of Standards) should be consulted.

Helmets are made to cover the head completely and to rest on the shoulders of the operator. Many operators prefer the use of the helmet.

In the case of arc welding it is very necessary that the electrode holder be so constructed that it is impossible for the worker to touch any live part with his hand while holding the handle. There are many in use which do not comply with this elementary requirement. Another important point is that one side of the circuit, that which is connected to the article to be welded, be grounded. There should be no fuse in the grounded conductor, but a circuit-breaker may be placed therein if both poles of the circuit are broken simultaneously. Except when the arc is actually maintained, the electrode is at the full voltage of the circuit.

Insulated holders are supplied for both metal and carbon electrodes, resembling each other in design but differing in the manner in which the electrodes are held. As welding with a graphite electrode requires greater current, and consequently greater heat in the arc, a disk is supplied to protect the hand from the intense heat. This protective disk is not so necessary on the metal-electrode holder.

351. Grounding of Furnace Frames.

Where furnaces have exposed noncurrent-carrying metal parts with which the workman must frequently come in contact, and which are exposed also to possible contact with the metal material being handled while such material is in contact with grounded floors, machines, or other such surfaces, these exposed metal parts should, in general, be grounded. The rule requires this grounding where the frame or other noncurrent-carrying metal parts inclose current-carrying parts which exceed 150 volts to ground, on account of the danger of electric shock to workers which then exists in addition to that of severe short-circuits which exist also at low voltages.

Insulating floors which would prevent both dangers are generally impracticable from the nature of the processes or surroundings.

352. Guarding Live Parts.

In most electric furnaces live parts can be readily guarded against accidental contact by persons or materials. The nature of the location and processes makes even low potentials a great menace, as metal material and the large current capacities involved can cause short-circuits.

For parts of more than 150 volts to ground shielding is the more essential on account of the increased shock hazard as voltage increases, and spot welding, requiring bare movable electrodes, should therefore be confined to lower voltages.

353. Storage Batteries.

See discussion of section 13.

354. Transformers.

The advisability of providing a fireproof inclosure for oil-immersed transformers and other apparatus having considerable oil in contact with the windings is far greater with utilization equipment than in the case of stations, since the surroundings are more frequently combustible and much more congested, and the greater number of employees, together with their probable lack of electrical training, tend toward greater property loss as well as increased danger of panic and accident in case of rapidly spreading oil fires from such oil-insulated apparatus.

Concrete vaults have been used extensively for this purpose. Where switching by unqualified employees is necessary, it is a good plan to provide lever-operated switches with handles projecting on the outside, so as not to necessitate entering the vault to operate the switch.

355. Lightning Arresters.

Lightning arresters, in general, may be placed on overhead lines, and their use within buildings other than stations may be thus avoided. It is advisable, where they are for any reason placed within the building, that they should be made inaccessible because of their possible danger to persons in the vicinity during violent discharges. Although it has been felt by some to be unreasonable to require lightning arresters, even where low-voltage distribution circuits are considerably exposed, their use is recommended as a protection to the equipment and devices attached to such circuits within buildings if the outside circuit is exposed in overhead construction for a considerable distance—say, 1,000 feet or more—in locations subject to severe lightning.

Sec. 36. LIGHTING FIXTURES AND SIGNS

360. Grounding.

It is sometimes practicable to place lighting fixtures and less often other fixed electrical devices, such as heaters, cash registers, etc., where no grounded surfaces (plumbing, machines, damp floors) are within reach, and in such cases grounding is unnecessary as a protective measure. Lighting fixtures may be placed out of reach on ceilings and controlled by separate switches, frequently with improvement in convenience and illumination alike. If, however, fixtures must be placed within reach from grounded surfaces, and the entire exterior surface can not be of suitable insulating material (as with porcelain or composition sockets), the grounding of the fixture itself becomes necessary. This is especially so when the surrounding atmosphere is damp, as in baths, laundries, stables, and packing plants.

The grounding of fixtures attached to conduit and similar wiring systems is readily accomplished through the conduit or other metal covering. With wiring having no metal covering, a separate grounding wire may be necessary. Grounding by attachment to a grounded circuit conductor has been suggested, but in general it is inadvisable. Grounding to neighboring water, heating, or other piping systems (except gas) will usually be feasible and provides an effective and desirable protective connection.

The grounding in case of combination gas and electric fixtures presents a peculiar problem. Gas piping is sometimes electrically discontinuous by reason of comparatively high-resistance joints. Its repair is carried on regardless of electrical considerations, and it contains an inflammable gas. For these reasons the use of gas piping as the sole ground for a fixture should generally be discouraged. (See sec. 9.) Insulation of the fixture from the gas pipe seems to be unnecessary where the fixture is otherwise well grounded and is distinctly bad practice where no other ground is available for the fixture.

Combination fixtures and the proximity of gas pipes to electrical conductors should be avoided wherever practicable from both life and fire-hazard viewpoints.

361. Receptacle for Convenience Outlet.

Screw-shell sockets are standard and are used with very little hazard as lamp and fuse holders, especially when the shell is connected to the identified (grounded) conductor. Under normal operation in fixtures the socket is, of course, filled by a lamp and is also usually out of reach of small children.

Screw-base convenience receptacles, less than 5 feet above the floor, even if the socket is covered by a small door when not in use, present an unnecessary hazard in residences. Bayonet-type flush receptacles present no externally exposed current-carrying parts, and should always be installed as appliance receptacles.

362. Exposed Live Parts.

Many shocks have resulted from the exposure of live parts where the ordinary public has access, and the hazard is greater where near metallic piping or plumbing liable to be grounded. The frequent incidental and imperfect grounding of electrical circuits at other places makes it possible to establish a circuit between the exposed live parts and the piping. Under certain conditions ordinary lighting-circuit voltages are sufficient to cause death, particularly in damp laundries, bathrooms, and similar places.

By identifying circuit conductors as is now required in some cases by the National Electrical Code, it becomes easy to fix the inner screw shell of all sockets and receptacles at approximately earth potential, reducing the probability of breakdown from the inner screw shell to the external metal shell of the socket, and preventing the danger otherwise present from touching the ungrounded lamp base and at the same time the grounded outer casing.

363. Signs.

As installed in the past, many electric signs have been so arranged that access for replacing lamps or making repairs has been both difficult and dangerous. When the sign overhangs a sidewalk, there is added to the danger of workmen being shocked or of their falling from the sign, the danger to the public by falling tools and materials. These are minimized by providing the workmen with suitable facilities for access, together with means for securing themselves to the sign.

364. Connectors for Signs.

Usually signs are elevated above a sidewalk or roof, and renewals or new connections are made at considerable hazard. It is therefore a safety measure to provide proper connectors for facilitating connections and also to provide these with the necessary guards so as to leave no exposed live parts.

365. Isolating or Guarding Lamps in Series Circuits.

(a) **Elevation.**—Series circuits are, in general, very objectionable in buildings or in spaces accessible to the general public. Even on poles just out of easy reach, high voltages may, in places of public gathering, expose curious persons or children, and the severity of the high-voltage shocks possible under such circumstances warrants a much greater degree of safeguarding than is necessary with parts of lower voltages such as are common with constant-voltage systems for interior wiring.

(b) **Suspension of lamps.**—Even the supporting or lowering devices for lamps on poles or on span wires deserve careful guarding. Some companies use insulating rope to protect from shock any careless persons who may reach up and touch the lowering devices. Other companies place the lowering devices so high that the trimmer must climb the pole to reach them, and unauthorized persons are prevented from tampering with them.

366. Safe Access to Arc Lamps.

There are several devices obtainable which accomplish the purpose of automatically disconnecting the lamp as it is being lowered. Where the lamp is stationary a separate switch must be provided to accomplish this purpose.

Sec. 37. PORTABLE DEVICES, CABLES, AND CONNECTORS

[Not including those for communication systems]

370. Insulation.

In most portable appliances now in use in this country the dielectric between internal live parts and external metal parts is the sole protection of users against shock. The material most suitable for this insulation depends on the uses and the location. Treated wood fiber may be satisfactory where the surroundings are dry and the temperature not too high, but is not satisfactory in damp locations. Mica and certain other materials are suitable where much heat is developed, as in an electric iron. The designer must use a material which while adequate is not too expensive.

The problem is particularly important, because portable appliances, from their nature, are liable to be carried near grounded surfaces, and at the same time are subject to harder usage than are fixtures and fixed devices.

371. Grounding of Frames.

(a) **When adjacent to grounded surfaces.**—The grounding of external metal parts of portable appliances is no less to be recommended as a safety measure than the grounding of lighting fixtures, motor frames, and other fixed devices. Indeed, the fact that portable appliances are more handled, and may be carried into close proximity to plumbing and similar grounded surfaces makes their grounding even more desirable. With portable appliances the grounding can be accomplished through a portable grounding wire. To protect this properly, while securing at the same time sufficient flexibility, is a problem which has been solved by the use of a grounding conductor in the portable cable, the one used as grounding wire to be used only for this protective purpose and not also for carrying current normally. The use of the grounded and identified circuit conductor as a means of grounding portable frames has been advocated but is open to serious objections. If this conductor should become interrupted at any point in the installation, the exposed metal parts would become alive.

The cord with an extra safety conductor for grounding the frame involves some complications, since it requires a polarized plug and receptacle with an additional contact. These are available on the market and are recommended for all future installations, especially for industrial premises using 220 volts for portables.

Because of the greater difficulties involved in grounding portable devices than in grounding fixtures, and because of the inadequate supply available of portable cord and connectors suitable for accomplishing the grounding in the manner above outlined, it has been deemed, for the present, advisable that the rule only recommend grounding. The especial need for such protection is emphasized in the case of portables on circuits of more than 150 volts to ground, where the life hazard is so greatly increased over that with lower voltages, that not even the present difficulty in securing suitable cord and

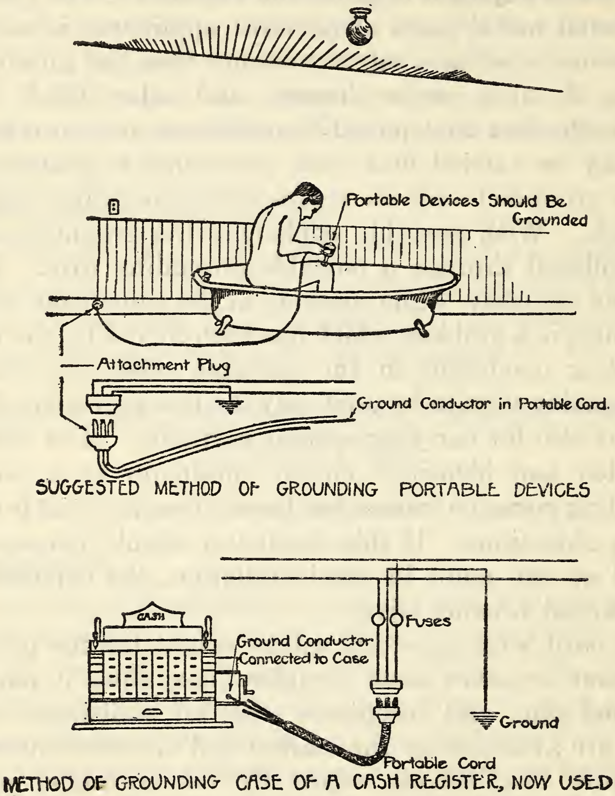

FIG. 32.—*Grounding of portable appliances*

connectors arranged for grounding should excuse the absence of this protection. The method of grounding is shown in Figure 32.

(b) **Sockets and fixtures of insulating material.**—It is more feasible in many instances to provide devices having insulating coverings in lieu of devices with metal covers or cases separately grounded. Porcelain sockets are examples and are now much used in locations within reach of grounded surfaces, such as basements and bathrooms.

372. Cable Connectors.

It is undesirable and unsafe to provide single-pole connectors with which it is possible to break one conductor of the circuit while the other conductor or conductors are left connected, thus leaving the disconnected conductor alive at the connector and exposed to possible contact or to grounding on near-by grounded surfaces, pipes, etc. The device with which such a connector is used will also be left alive. With the circuit broken and device alive persons may believe the device dead and handle it, thereby exposing themselves to possible shock. Connectors are available that accomplish the purpose of the rule; in the smaller capacities they are known as attachment plugs. The ease of making large-capacity connectors single-pole might prompt such practice, but it is much more desirable to arrange them so that all poles are necessarily disconnected when the circuit is opened and more important than for the smaller capacities.

The swivel type of connector is less desirable than the bayonet type, which disconnects all poles simultaneously so that the operation can, therefore, not be interrupted during disconnection so as to leave a single pole connected and the portable cord and device possibly alive from this source.

373. Identified Conductors, Cords, and Connectors.

Where portable cable must be depended upon to ground external metal of portable devices, the separable connectors must, of course, be of a type such that no connection of normally current-carrying parts to the terminals designed for the grounding wire is possible with ordinary care by the person making up the portable cable and its attached connectors, nor in any event by the person connecting the separable connectors in practical use of the device. The employment of a separate and distinctly marked grounding or safety wire (a third wire with two-conductor cables) makes mistakes very unlikely. The safety terminal on each side of the separable connectors should be no less distinctly marked.

374. Use of Portables and Pendants.

(a) **Voltage limit of portables.**—The use of portable and pendent conductors has always been associated with higher degrees of hazard than fixed wiring even on the lower voltages. They are more subject to wear and tear than other wiring and therefore prohibited on voltages of more than 300 to ground except for authorized persons. In many car houses special low-voltage circuits are run in car pits and other places where the use of some kind of portable light is necessary, to avoid the extra danger of the higher trolley voltage.

(b) **Use of fixed receptacles for portables.**—Intelligent judgment on the part of the wiremen will be far-reaching in obtaining a safe installation. All sockets and receptacles, including those for portable conductors, should always be connected so that the more exposed current-carrying part is connected to the grounded side. In the Edison type of socket and receptacle this will be the inner screw shell.

(d) **Strain relief.**—Strain relief is sometimes provided in the manufacture of devices. In separable connectors for irons a clamp which is intended to clamp the individual conductors is provided; but in such devices as sockets and small portable motors the portable cord is knotted or taped so as to provide the necessary strain relief. In some types of sockets a strain relief is provided for in the construction of the socket.

(e) **Worn and defective portables.**—When the conductors of portables show evidence of wear, or when the conditions of their use are more severe than those for which they were designed, such as by being moved into damp locations, the conductors should be renewed or replaced. Article 6 of the National Electrical Code in rule 609 describes commercial types of cords suitable in various locations for portables and pendants, including a convenient tabulation.

Sec. 38. ELECTRICALLY OPERATED INDUSTRIAL LOCOMOTIVES, CARS, CRANES, HOISTS, AND ELEVATORS

380. Guarding Live and Moving Parts.

(a) **Guarding and isolation.**—The number of injuries occurring in electric cars to motormen, conductors, and even the public by contact with exposed live parts or ungrounded (and accidentally alive) metal frames is very considerable, probably because the voltages are relatively high, being usually 500 or more to ground, as compared with the common 110 volts to ground of lighting circuits in general use. Many railway companies are adopting very thorough guarding and grounding measures to obviate these hazards. Elevator cages, cables, and shop locomotives present to a somewhat less degree the same dangers, and the efforts to protect them are by no means so uniform or complete. The location of automatic circuit-breakers and fuses so that flashes will not burn persons is now receiving more attention than formerly.

(b) **Conductors.**—In any moving vehicle all parts are subject to more wear and tear than in a stationary object of any kind. This is partly due to vibration, dust, dirt, and grease, partly due to frequent starting and stopping and, in the case of cars, exposure to weather. Therefore the wiring should be installed in a substantial manner with no wires which may be caught and broken and with which people may come in contact. Good workmanship, in general, tends toward reliability in operation as well as safety and necessitates a minimum amount of repairs.

(c) **Elevator hoistways.**—For wires in elevator shafts used in the operation of the car it has been found good practice to install them either in conduit or armored cable. Exposed wires in hoistways in past practice have given rise to much trouble, and the breaking of a wire at a critical time may imprison persons in the car.

Other conductors not specially concerned with the operation, control, or signals of the elevator are permitted if inclosed in conduit or armored cable, but there must be no outlets or taps installed in the hoistway. Outlet and junction boxes may be placed outside of the hoistway so as not to necessitate a person going into the hoistway in order to pull in or renew conductors. The reason for this requirement can readily be appreciated when it is known that the lives of those working in the hoistway under such circumstances are endangered, and such procedure would tie up traffic unless the work were performed during hours of no traffic. The rule is, however, not intended to prohibit the placing of boxes in the conduit run to permit the anchoring of cables in tall hoistways where the weight of the cable might cause it to pull apart.

The voltage of circuits brought to the car is limited to 750, which will admit the 550-volt circuit. Higher voltages are permissible for the motor drive, and except for running up the hoistway they must be confined to the penthouse from which unauthorized persons are excluded.

In general the signal and control circuits should not exceed 150 volts to ground. Arcing is likely to occur in push buttons if voltages higher than 300 are used.

(e) **Apparatus insulated and grounded.**—When connected to grounded large-capacity circuits, the reliability of apparatus, such as motors, may be greatly increased by insulating the frames from ground. It is therefore advisable to insulate the frames of electrical apparatus from the ground and from the structural or piping systems on cars, cranes, and hoists when the frames are isolated and guarded so as to remove the hazard of anyone inadvertently touching at the same time the frames and surrounding grounded metallic objects. When, as in the case of an air compressor and its motor, the motor and driven machine are mounted as a unit, the entire unit may be insulated from the car body and isolated or guarded like a current-carrying part. This will involve in the case of an air-compressor unit an insulating joint in the air pipe, and the air piping system must be effectively grounded.

(f) **Collector wires and third rail.**—In the case of crane collector wires isolation by elevation is the usual procedure. When installed where long metal bars, rods, or pipes are handled, the elevation should be ample. Where sufficient elevation is not feasible, gutters of wood have been employed as a guard for trolley wires. For third rails, especially where they pass through yards, wood guards have been found effective in preventing accidents from shock.

381. Grounding Noncurrent-Carrying Parts.

A wooden barrier over the top of the boom of a crane, derrick, or similar equipment mounted on tracks with overhead trolleys will prevent the boom from being raised against the trolley. It may be impractical to guard the metallic boom or cables so that contact with the trolley can not be made in any position.

For the safety of persons who may have to go on the car roof for maintenance or repair and to prevent short circuits conducted through the car in case of a broken trolley, it may be advisable to have no exposed grounded metallic object above the car roof. In the case of metallic parts that originate below the car roof and extend above the roof, an insulating joint will be required at the roof to effectively separate the part above the roof from that below, or the entire part above the roof may be protected by insulating guards.

384. Subway and Car Lighting.

Illumination is one of the best means of preventing panic, while darkness encourages it. The assurance of adequate illumination in emergencies is a first consideration in theater lighting and the same applies to passenger subways. In some cases storage batteries are carried on cars and are automatically switched on when other sources of energy for lighting fail. In some cases, sufficient illumination is provided for the entire subway from two sources, one being automatically switched on when the other fails.

A committee of the Illuminating Engineering Society has investigated subway lighting and made the following recommendations.

A separate system of lighting in addition to the service which is taken off the circuit of the third rail should be installed on station platforms, fed by a separate source of supply such as a secondary system fed from a transformer line direct from the main power station. In addition to this, as a matter of protection, it is suggested that a third system of lighting be available fed directly from a separate power house of the company or a separate system of supply from another company. This source of supply should also feed an additional system of lighting in the tunnel so that if for any reason the line from the main power house or secondary system of supply fail, the third source of supply, being an outside source, would still be available.

The minimum intensity of illumination permitted for station platforms should be ½ foot candle. Present practice in New York averages 1.2 foot candles. For stairways and aisles present practice averages 3.4 and the minimum permissible should be 2 foot candles. Present values were measured on a horizontal plane 54 inches above the platform.

For subways between stations, or tunnel lighting, it is recommended that, for safety purposes, 40-watt lamps be installed not more than 60 feet apart on each side wall of the tunnel, 9 feet above the rails. This corresponds to $\frac{2}{3}$ watt per linear foot for each wall.

For emergency lighting of cars from a battery circuit, a lamp should be installed at each end of the car over the doorways and should supply from 10 to 15 c. p. The battery should be capable of furnishing current for two or three hours at least. Arrangements should be provided for automatic charging of the battery.

Regular car lighting, not intended for safety purposes, was found to average 2.9 foot-candles on a plane 42 inches above the floor, and a permissible minimum of 1.5 foot-candles is recommended (and is specified by the Public Service Commission for the first district of New York) when the operating voltage is only 85 per cent of the nominal substation voltage.

Sec. 39. TELEPHONE AND OTHER COMMUNICATION APPARATUS ON CIRCUITS EXPOSED TO SUPPLY LINES OR LIGHTNING

390. Guarding Noncurrent-Carrying Parts.

(a) **Protective requirements.**—The number of injuries to persons using telephones, fire-alarm boxes, and other devices has been considerable, because of the lack both of effective arresters and of means for preventing a voltage between external metal parts of such devices and the ground or grounded floors on which the persons must stand, or between these external parts and plumbing within reach. The grounding of fire and police alarm box cases and their accessible metal parts is now almost universally supported, but is still neglected in too many places from a fear that the dielectric between internal current-carrying parts and the case will not withstand the strain from the voltages to which it is subjected by crosses, with supply lines. Such a weakness should evidently not be allowed to exist and should never be made a basis for permitting a condition by which high voltage may exist on external metal to which persons have access. Telephones usually should have efficient arrester protection, but with fire-alarm circuits and some other signal circuits the reliability of the circuit necessitates the omission of arresters scattered along the line and not susceptible to immediate attention after operation, and reliance in these cases must be placed wholly on the grounding of exposed metal parts of apparatus accessible to the public.

(b) **Fire and police alarm boxes.**—Telegraph instruments expose so little surface to personal contact that the danger of shock is considerably reduced, and it has seemed reasonable to permit use of arresters whose breakdown voltage is somewhat higher than will suitably protect users of telephones, which present much larger metal areas to contact with the hand and face.

391. Guarding Current-Carrying Parts.

Subway types of telephones and other signal apparatus have been developed which provide protection against breakdown of insulation under conditions of dampness prevailing. Since the cases of such equipment will be grounded where signal circuits are exposed to neighboring high-voltage lines, unless suitable protectors are used, adequate for the insulation, the principal personal hazard will be through cords.

Where protectors are used, a cord having insulation capable of withstanding perhaps double the breakdown voltage of the arrester should usually provide adequate protection in dry places, but in damp places additional protection is needed. Where no protectors are provided, as in some cases at police boxes, train-conductor call boxes, and similar locations, very effective cord protection by insulating tubing or grounded metal tubing is evidently essential.

392. Protection Against Induced Voltages.

The voltage induced between the terminals of communication apparatus connected to overhead circuits and ground depends on a great many factors, and in general it will be found simpler to measure it than to compute it. This induced voltage can most readily be measured by an electrostatic voltmeter with the communication circuit in normal operating condition. When an electrostatic voltmeter is not available, the voltage can be estimated from the indications of an electromagnetic voltmeter.

In the case of balanced three-phase circuits, the induced voltage in near-by circuits is predominately electrostatic for the types of circuit ordinarily used. The voltage limit of 150 volts named in the rules would exceed the voltage which would be induced electrostatically by a balanced nontransposed 6,600-volt circuit, however arranged, upon communication circuits on the same pole line 6 feet away.

Frequently a change in configuration or the transposition of conductors in a metallic-return supply circuit will assist materially in reducing higher induced voltage on neighboring communication circuits to less than 150 to ground.

393. Grounding of Arresters for Communication Systems.

By comparison of these grounding requirements with those of section 9, it is seen that these are less severe, although generally of the same character. Since these arresters are not called upon to operate frequently, the protection afforded is therefore not so constantly demanded as that of circuit or equipment grounds; therefore artificial grounds of comparatively high resistance are less likely to dry out so as to still further increase the resistance and reduce the protection afforded.

Part 4.—RULES TO BE OBSERVED IN THE OPERATION OF ELECTRICAL EQUIPMENT AND LINES

Sec. 40. SCOPE AND APPLICATION

Electrical equipment can not always be completely guarded, and frequently it becomes necessary to remove, temporarily, guards which have been installed. Therefore, the safety of employees must be attained, to some extent, through their observation of precautions while at work about electrical equipment.

Where work on or about electrical equipment is incidental to manufacturing processes, or the conduct of nonelectrical business or domestic activities, very little precaution can be expected from the employees and guards must, therefore, be more complete and more nearly "foolproof." However, to reduce interruptions to service to a minimum, electrical workers must frequently work near exposed or partially exposed live parts and must, therefore, rely to a great extent upon operating precautions, in addition to such guards as are practicable in particular instances.

Sec. 41. SUPPLY SYSTEMS—RULES FOR EMPLOYERS

410. General Requirements.

A. Interpretation and enforcement of rules.

1. *Distribution.*—To avoid misunderstandings it is essential that employees be thoroughly acquainted with the safety rules they are expected to observe, and as differences of opinion are liable to be too great on unwritten rules, the issuance of written rules to each regular employee is necessary. It is desirable that such rules shall be reasonably complete, in

order that an employee may understand the relation of his work to that of others in the organization.

In the case of temporary employees, or those employed in special lines of work, who do not need to be familiar with all the rules, only a portion of the rules need be supplied. Enough rules must be furnished each individual to care for probable emergencies under which the employee could be expected to act. The intent of rule 400 will be met where company rule books incorporate the necessary rules from the safety code, even though the wording may be altered to conform to the terminology elsewhere used in such rule books.

2. *Interpretation.*—To the same degree that an employer is responsible for the prevention of accidents among employees, he must also be responsible for the interpretation and enforcement of rules by which the protection of the employees may be secured, subject, of course, to proper interpretation or modification of such rules by the regulative body having jurisdiction.

B. Organization diagram.—The organization diagram is important in small as well as large organizations, so that teamwork will be encouraged and the acts of each workman be governed by intelligent appreciation of his relation to the organization as a whole. Emergencies are thus more readily and safely met and service correspondingly improved. It is particularly important that each man in charge of the other men should have the relative duties of these clearly defined, and so be better able to direct the conduct of work.

C. First-aid rules and physicians' addresses.—In emergencies memory can not always be depended upon. Even the best-trained man may lose self-possession, and without a suitable guide serious errors and delays may result. The address list and emergency rules should be in the possession of each employee, as well as being posted in conspicuous locations, since reference to these should supply the necessary instructions at such times.

D. Instructing employees.—The instruction of employees in methods for the resuscitation of persons rendered unconscious by electric shock, for the temporary treatment of wounds and fractures, and for the extinguishment of fire, is important in avoiding panic or nervousness when emergencies arise.

By actual drilling the methods become a part of the employee's regular habit, and dependence can be placed on their being properly used when need arises. With some companies such drills are given by the various foremen; with others they are given by a staff of instructors, who also instruct the employees in methods of electrical operation.

Many companies have established schools for instruction in operation, and where this is practiable the enthusiasm and teamwork brought about tend toward better as well as safer service. Local bulletins, suggestions, and question boxes, working models of poles, manholes, and equipment all serve to develop and maintain the necessary active interest and cooperation of employees.

E. Qualifications of employees.—The mental and physical condition of employees constitutes an important factor in the character of service rendered by utilities and is no less a factor in the accident record. The choice of employees has in the past been less carefully made than will be the case in the future, since the various compensation laws impose on the industry the disability losses entailed by defective men as well as by defective installations.

Suitable choice of workers also demands inquiry into their use of intoxicants or certain habit-forming drugs. Users of either, even to so mild a degree as would ordinarily excite no comment, may become sufficiently affected to impair their alertness and judgment, and because of the special nature of electrical work this greatly increases the danger to others as well as themselves.

The initial fitness of a worker does not insure the continued maintenance of such fitness. This must be secured by instruction and frequent examination, and those companies most carefully pursuing such follow-up methods claim that the expense of such constant supervision is small and the results, through better service and reduced disability, are very marked.

F. Chief operator.—In all operating organizations a responsible head is essential to prevent conflict among various parts of the organization and to secure a smooth and efficient operation. This need is very evident in operation involving so much danger to workers as does that of electrical supply systems. Many companies have arranged a very definite division of responsibility, including in their organizations a chief operator, who directly controls all operating matters affecting the safety of work on or about transmission lines and interconnected feeders and keeps informed of all conditions affecting the safety of public and workers.

Such an arrangement is of the greatest importance in emergencies, when general understandings, which are unreliable at the best, break down entirely. The more diversified organizations will frequently require a chief operator, whose entire time is given to proper correlation of work for the safety of employees and proper maintenance of the service.

Sometimes it may be impracticable to have the entire system in charge of one chief operator, and an arrangement may be made by which different portions of the system are assigned to different chief operators, who will have full charge of the safety of operations for their respective districts. The title of the chief operator in any particular organization may, of course, be superintendent, engineer, or otherwise, but for convenience in the rules the designation of chief operator is adhered to throughout. With smaller or less complicated organizations, the chief operator will frequently

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have other duties occupying most of his time but from which he can detach himself when necessary to direct operation.

G. Responsibility.—In every group of workers, however small, one must always be understood to be the leader or senior, to give and receive telephone messages and to correlate the work of the group. He may be called in different localities boss, leader, or by any term, but for the purpose of these rules is not considered as ranking above those other employees with whom he is at the time associated, the arrangement being solely for the safety of the workmen.

The fear has been expressed that assignment of any definite rank to such a person, if only for convenience, and however temporary in nature, would be followed by a confusion of such a "leader" with the regular "foreman" in the minds of electrical workers, and in some localities additional pay might be demanded on this basis. The rules are, therefore, so worded as to indicate clearly that no higher rank is intended to be conferred.

411. Protective Methods.

A. Attendance.—Some tendency exists in certain cases to encourage the use of stations not under regular attendance during operation, and automatic substations are now coming into general use in connection with electric railways. In such cases it is, of course, necessary to use adequate means for preventing the entrance of unauthorized persons, since no qualified person is present to warn them from existing hazards. Where generating equipment is installed, this is important even for stations operating at low voltages, since the interruption of their service may have far-reaching and possibly dangerous effects.

B. Requirement for two workmen.—Where a workman on dangerous work is accompanied and watched by another person, he is ordinarily less nervous and can be cautiously warned when necessary. He can also be saved from unnecessary movements and aided in many ways so as to make the work as safe as possible. In case of accident or injury he can be quickly aided and additional help called for if necessary.

Many companies make the assignment of two men mandatory on any highly dangerous work, and some have closely defined the circumstances under which two men will be required. No attempt is made in the rule to define the exact conditions under which two employees shall invariably be provided. The local conditions will, of course, be considered by the regulatory bodies in considering specific cases. In some cases where only one qualified employee is regularly employed, the rule may necessarily be waived, or the employee may be accompanied by some person not fully qualified, but still capable of rendering assistance in emergency.

C. Unqualified workmen and visitors.—A certain number of injuries occur from unqualified employees or visitors venturing into the vicinity of live parts, and this practice should be prevented, as far as possible, by instructions from the employer to qualified employees in attendance to prohibit approach of such unqualified persons to live parts by means of warnings or otherwise.

D. Diagrams for chief operator.—The chief operator, however well acquainted with the system, can not be so fully informed that the details supplied by suitable diagrams or maps will not assist him in understanding messages received and make his instructions better safeguards for operation and for the workers. In emergencies much time may frequently be saved and sometimes dangerous mistakes prevented by reference to simple diagrams instead of dependence on memory or reference to log book or record sheet.

E. Instructions to employees.—Reasonably complete instructions to employees are one of the best means for avoiding mistakes in which an effort is made to work on the wrong equipment or lines, or too close approach is made to live equipment or lines without knowledge of their exact character and the attendant possible danger when working in their vicinity.

F. Protective devices.—The list of protective devices given does not, of course, completely cover all devices which will be supplied to workmen by the largest companies or for work of unusual character. The list is, however, made fairly complete and contains more devices than will usually be necessary at any one time in small stations or in the work of any one line gang. The rule states that a "sufficient supply of suitable devices" should be provided, the list serving purely as a sufficient illustration of devices which under various circumstances will be suitable.

G. Inspection of protective devices.—Leather belts appear to be especially subject to deterioration, and a careful check should be kept as to their strength being adequate.

H. Warning signs.—The unnecessary number of accidents to unauthorized persons in rooms containing electrical supply or similar equipment may be very considerably reduced by uniformly displaying at all entrances to such rooms suitable warning signs forbidding entrance to such persons.

I. Danger signs.—Even where only authorized persons have access, a judicious use of danger signs near portions of the equipment where current-carrying parts at high voltages are exposed, will serve to call attention of the qualified employees to the more particular points of danger for which guarding or isolation has not for any reason been provided.

The National Electrical Safety Code does not contain any requirements for audible signals in stations or industrial plants. However, such signals contribute essentially to the safety of employees, since a person in the vicinity can not help hearing them promptly. A visual signal may not be noticed until after a considerable lapse of time, during which a very serious hazard may exist, on account of an abnormal or dangerous condition of the apparatus. Wherever a visual indication of such a condition is deemed advisable, an audible indication by means of an electric horn, bell, or whistle should also be seriously considered. The most important signals should be connected to an emergency or alternate source of power, so that they may not be rendered inoperative when most needed.

The audible signal system may employ a code-calling method, which will prove effective in case of fire, failure of power, a runaway machine, an accident to an employee, etc. Loud-speaking telephones may also be used in some cases, as for instance between the load dispatcher, the operating superintendent, and the switchboard operators.

Sec. 42. SUPPLY SYSTEMS—GENERAL RULES FOR ALL EMPLOYEES

420. General Precautions.

A. Rules and emergency methods.—Regardless of the excellence of rules distributed to employees such rules will only be of full value in cases of emergencies in operation, when employees have become thoroughly familiar with them. Employers are required to distribute rules in order to make this information available and so promote the safety of the employees; each employee in turn owes a duty to others to know the methods which will best safeguard them as well as himself.

B. Heeding warnings, warning others.—A too frequent cause of accidents is the habit of unnecessarily taking chances by approaching live parts of equipment or lines. The cultivation of personal caution should be promoted by every employee as a duty to himself, his family, and his fellow employees.

C. Inexperienced or unfit employees.—Accidents are also unnecessarily caused in numerous instances by the undertaking of work, unsupervised, by employees who are not qualified to proceed except under supervision. It is always better to admit lack of full qualification than for an employee to endanger himself and others by recklessly undertaking work in which he knows he is not sufficiently experienced.

D. Supervision of workmen.—Although a man may be experienced for his own particular class of work—as, for instance, a painter, carpenter, etc.—he may be quite ignorant of the danger in approaching the live parts of electrical equipment and lines with which he is inexperienced. The regular station attendant and the experienced lineman may approach such parts with comparative safety. It is therefore advisable that men, without special experience which will safeguard them when about electrical equipment, shall be under the direct supervision of an experienced and properly qualified person while in such locations.

F. Live and arcing parts.

1. *Treat everything as alive.*—As it is frequently impossible to see whether equipment is operating, and just as impossible to know whether lines are crossed at a distant point with other live lines, it is usually better to consider the electrical equipment and lines as alive and treat them as if in that condition.

2. *Protection against arcs.*—In many cases serious burns have been avoided by use of suitable gloves on the hands and goggles covering the eyes, and when flashes are to be expected such protection should be provided. Where possible, of course, the exposure to arcing should be entirely avoided by keeping away as much as possible from parts at which arcing can occur.

G. Safety appliances.—The safety appliances provided should be used by the employee. Unfortunately there still exists a disinclination on the part of certain employees to use the protective devices, under the mistaken impression that they are intended chiefly to safeguard inexperienced or physically defective employees, and are unnecessary and an obstruction to experienced and physically fit employees. This is a fallacy. The devices supplied follow the experience of the entire country, and this must necessarily be superior to the judgment of the individual as to the advantage or disadvantage of such devices.

H. Suitable clothing.—The suitability of his clothing should also be considered by every employee, since unsuitable clothing or trinkets may lead to some accident or increase the resulting injury.

I. Safe supports.—One of the most common causes of accidents is the insecurity of supports for persons whose work is necessarily on elevated structures, such as ladders, scaffolds, or poles.

Wooden ladders are often made with their side pieces of small cross-section in order to reduce their weight and are reinforced with wire or metal strips to give them the required strength. This type of ladder has been used considerably by electrical companies because of its light weight. Special care should always be practiced when using these ladders on overhead lines or near station equipment. If such a ladder handled by workmen comes in contact with any live part, a serious or fatal accident may result. They should never be worked on where it is possible for an employee to come in contact with live parts and the metal reinforcement (which may be grounded) at the same time. Many operating companies do not permit their use, owing to the likelihood of improper use.

For good practice in the design and use of ladders see Safety Code for Ladders, A. E. S. C. A 14—1923.

J. Safety belts.—Precaution both in climbing and in attaining a safe position, including usually the use of a suitable safety belt, will well repay the slight time and trouble involved. It sometimes happens that a safety belt or spur strap or similar device will be continued in use by an employee far beyond its safe life, and this danger should be avoided by submitting such devices to the employer for inspection and necessary test.

K. Fire extinguishers.—See discussion of rule 106.

L. Repeating messages.—Many accidents are due to misinterpretation of instructions or information, and the repetition of unwritten messages is widely practiced to avoid misunderstandings of this kind.

The rules of some utilities require that both parties make a written record of telephone messages, which are preserved for reference, and to assist the memory on details. This is of particular value for long messages.

421. Operating Routines.

A. Duties of chief operator.—In order that the chief operator may properly direct operation in so far as safety is affected, he should keep well informed regarding the operating conditions of the system under his jurisdiction, and the necessary records and operating diagrams of equipment and devices should be kept so as to be quickly available for his reference. The decisions of the chief operator require sound judgment and prompt attention. Loss of time in learning the conditions in order to act properly must be reduced to a minimum. It is clearly impossible to keep all records in sight, but the best results should be obtained by having records at hand, and the more important features, such as information as to whether circuits are open or closed, and as to where men are working, noted on diagrams in plain sight. In small stations, where the switchboard controlling all important circuits is in sight of the chief operator, the condition of the circuits, whether open or closed and whether men are at work upon them, will be thus sufficiently indicated, and such a switchboard may serve in lieu of operating diagrams as an equivalent device.

In some organizations the duties of chief operator are too heavy for a single person, and these duties are necessarily subdivided along lines determined largely by the physical arrangements of the operating system. In such cases, however, and especially where one or more stations feed into an interconnected system, either the reporting of all to a single head or the drawing of very definite boundaries between jurisdictions of the various chief operators for different parts of the system becomes indispensable for avoiding dangerous conflicts of judgment and of instructions. Where any one station, however, feeds outgoing lines not also fed from any other source, it is very simple for the operator at such a station to perform the duties of chief operator so far as such outgoing lines are concerned. He may be called chief operator, division operator, or simply station operator, but so long as he is duly vested with authority over the safe conduct of work on such lines, including the opening and closing of circuits and similar duties, the purpose is accomplished and his records and reports can in turn be submitted, if the plan of the organization so requires, to the system operator (or otherwise designated employee) in supervisory charge of the entire system.

B. Duties of foreman.—The importance of careful supervision of work by foremen can not be overestimated. Where foremen are held responsible for the safety of workmen under their direction, much physical unfitness can be observed and guarded against, and where men are always fit and carelessness or evasion of the operating rules is not tolerated, the experience of utilities indicates that the opportunities for accidents are distinctly reduced.

D. Special authorization.—In order that the chief operator may be sufficiently informed of operating conditions of the system, and particularly that he may be in a position to intelligently give directions for the protection of workmen, it is desirable and with many utilities the regular practice that the chief operator or other official in charge be notified and his permission secured before work is begun on high-voltage lines and before lines are killed at stations for the protection of workmen. Before placing station equipment in operation in an emergency it is also advisable that the chief operator be informed of such unusual conditions.

Exceptions are given to the general rule, to care for emergencies and also for cases where sectionalizing switches of less than 7,500 volts are opened by authorized workmen at places other than stations, but with provision that the chief operator should be notified as soon as possible after advantage has been taken, for presumably good reasons, of any exception permitted, in order that the change in the system's operation may be understood by the chief operator without unnecessary delay.

E. Restoring service after work.—One of the most serious possibilities for hazard in connection with work on supply lines is that, being carried on by gangs and usually at some distance from a source of energy, telephone messages or similar means must frequently be depended upon to enable the lines to be disconnected from the source of energy and reconnected for service without unnecessary delay or injury to the service rendered the public. Safety for the workmen must therefore depend upon very clear understanding between those opening circuits for the protection of workmen and the workmen themselves. The advantage of assigning to the chief operator the responsibility for safe conduct of work is that a regular procedure can thus be best carried out in assuring that men are all clear of the supply equipment, or lines in question, before equipment or lines are again made alive. The rule requires that a report must be made by each man, or by some authorized person for each man who has been at work, before the closing of switches which will make the lines alive may be undertaken.

F. Tagging electrical supply circuits.—This rule defines the character of circuits which must be tagged to prevent careless closing while persons are at work thereon. In general low and moderate-voltage circuits, unless killed at stations, need not be provided with "Men at Work" tags where workmen are engaged thereon. Still, where work is especially dangerous, by reason of close proximity to high-voltage lines or for other reasons, many utilities do tag even low-voltage circuits on which men are at work, so as to permit intelligent and rapid action by the chief operator or switchboard operator in any emergency. It is probable that a wider use of tagging would often facilitate operations from the standpoint of continuity of service no less than from that of its safety.

The procedure by which one person may disconnect lines and tag them as a protection for other workmen, sometimes at distant locations, is covered in detail in section 45. Where a workman disconnects lines for his own protection at points where no operator is located, no detailed procedure is necessary, his own tagging providing sufficient insurance against reconnection.

Many methods are used by different operating companies to make "Men at Work" tags distinctive. For instance, this is often accomplished by the use of different color combinations such as red cards with black lettering.

G. Maintaining service.

1. *Closing tagged circuits which have opened automatically.*—Usually "Men at Work" tags will not be placed on live circuits of moderate voltages on which work is done with suitable protective devices. If for any reason, such as very high voltage or where special hazards are involved, these

rules or the practice of the utility requires the placing of "Men at Work" tags on any live circuit which is being worked on, the opening of automatic cut-outs on such a circuit should be regarded as possibly indicative of danger to workmen on the circuit, and the latter should not be made alive again until it is known that workmen are not endangered by the reconnection.

2. *Closing circuits operated automatically.*—In many cases the local rules will require that overhead supply circuits shall not be closed after opening automatically more than a limited number of times in close succession. Sometimes the local operating rules will assign a definite number of openings beyond which the circuit must not be closed without instructions from the chief operator. In the absence of such instructions, which are presumably determined by due consideration of the possible hazards from fallen and crossed wires and the advantages of maintaining reliable service, operators should take precaution to call upon the chief operator for specific instructions before reconnecting the circuit.

3. *Grounded circuits.*—In the same way the existence of accidental grounds on overhead lines may indicate serious danger to the public, and should be corrected without delay. Many cases might be cited where grounds indicated at stations have been concerned in accidents from fallen wires with which passers-by came in contact. The prompt removal of accidental grounds should be undertaken, also giving proper consideration to the disadvantage of interrupting service unnecessarily, where the safety of the public may also depend in any way upon the maintenance of such service. Prompt patrolling is always desirable.

H. Protecting traffic.—Where wires are fallen in places where traffic occurs, a considerable hazard exists, since passers-by may unwittingly or carelessly touch these wires. The number of injuries and fatalities from this cause is unnecessarily high, and it may be reduced somewhat by suitable instruction of the public. In some cases, however, these contacts occur at night, or to small children not readily subject to instruction. In some cases, also, even where a watchman has been stationed to warn passers-by or has voluntarily undertaken such a duty, some other person has neglected the warning. Ordinarily, however, the warning is accepted, and without such warnings a very much greater number of fatalities would have occurred from fallen wires than has been reported.

The complete elimination of this trouble is impossible, but the reduction of the number of fallen wires is possible in a number of ways. Among these may be mentioned the suitable cooperation of municipalities and utilities in trimming of trees to allow safe clearance from lines, and thus prevent one of the commonest causes of falling wires. The abandonment of the use in too long spans of small sizes of soft copper wire, which stretches under load and swings against adjacent conductors, is also to be encouraged. These construction matters are treated of in part 2 on line construction.

I. Protecting workmen by switches and disconnectors.—With high-voltage circuits, where oil switches are commonly employed to interrupt the circuit under load, air-break disconnectors are generally also necessary and usually inserted to obviate the slight leakage which sometimes occurs through oil switches and which would seriously endanger persons working on lines disconnected from the source of energy only by those oil switches. This danger usually exists on circuits of more than 750 volts, unless the oil is very clean and free from moisture. The grounding of a circuit as required by rule 423, where circuits are killed at stations for the protection of workmen, will, of course, largely remove this danger. The air-break switch also has the advantage of giving clear visible indication as to its position, whether open or closed, while with oil switches it is sometimes not certain that the oil switch is actually open, even where the control lever is in the open position.

422. Handling Live Equipment or Lines.

A. General requirements.

1. *Touching live parts.*—It is necessary to have workmen about electrical equipment and lines thoroughly acquainted with the fact that contact with a single conductor is comparatively safe, but that contact with two conductors when they are at different potentials brings the body into an electric circuit, and may, according to the area of contact, the condition of the body at the point of contact, and the voltage concerned, cause more or less injury. Persons may ordinarily avoid touching more than one hand at a time to any conducting surface, but as the body must be supported at all times it is still important to see that the supporting surface (usually the ground or floor) is of insulating material before touching any live part with either hand.

2. *Wire insulation.*—The insulating covering of wire is subject to so many vicissitudes, among them mechanical injury and deterioration by atmospheric conditions, that reliance should never be placed by persons on such covering as a protection against shock. The appearance of the insulation may be good, but moisture or other cause may make leakage possible.

3. *Exposure to higher voltages.*—Especially during and after storms low-voltage lines exposed to higher-voltage lines in overhead construction are liable to have become crossed through actual contact or through tree leakage with the higher-voltage lines. When employees work upon low-voltage lines at such times, they should use extra precaution to make sure that no such leakage exists, or, as an alternative means of protection, should effectively ground the wires worked on. Insulating tools, gloves, and other devices

which may be suitable for low-voltage lines may be entirely inadequate as protection against the higher voltage.

4. *Cutting into insulating covering of live conductors.*—One of the more hazardous kinds of electrical work is the cutting of insulation on normally live conductors even if presumably killed in accordance with these rules. The cut in the insulation should be made with all the precautions which would be used if it were actually alive, until the line can be grounded, as required by rule 423. Serious accidents have too frequently occurred where insulation on live conductors has been cut without such precautions, in a mistaken belief that the conductor had been killed at the station, possibly through confusing the conductor with some other which had been killed.

B. Avoiding shock—Voltages between 750 and 7,500.—The rule requires that workmen should not approach live parts between these voltages within a distance of 6 inches unless protected by insulating devices between the workmen and the live part or between them and grounded surfaces on which they may stand or be otherwise supported. The distance given is small but is intended to provide for small inadvertent movements which an employee using reasonable care may still make, although aware of his position near live parts. The nature of insulating devices which might be used will vary with the condition, and sufficient devices to make improbable any contact with the live parts, even by considerable inadvertent movements, are desirable. Insulating devices over live parts, such as shields and coverings, should be of liberal dimensions and adequate thickness.

Gloves are necessarily limited in thickness and must, therefore, be the more carefully and frequently inspected, especially as the nature of their use subjects them to abrasion and, without great care, to splinters. Gloves also protect only a quite limited area of the body, and for this reason some companies are resorting to the use of insulating sleeves to extend this area and so avoid the somewhat frequent injury from contact with live wires by elbows or arms above the glove, where work must be done close to live parts.

It is regarded as preferable to work with the hands at a distance from the live parts through the medium of appliances, such as wood-handled tongs, pliers, saws, etc., and thus avoid the possibility that small movements or abrasions of comparatively thin insulating covers (either shields or gloves) may cause shocks. The development of insulating tools permitting considerable space from live parts has not yet been sufficient, so that all kinds of work, such as splicing and replacement of insulators can be conveniently carried on, but it is probable that future development will result in a very general use of such appliances and the maintenance by workers of greater clearances from live parts.

C. Avoiding shock—voltages exceeding 7,500.—Work on or about live lines or equipment of more than 7,500 volts should be undertaken only when absolutely necessary, and then only when the most thorough precautions are taken. Gloves which are effective against such voltages are liable to be too thick for convenient use. Insulating rods, tongs, and similar appliances have, however, been so developed that lines even of 100,000 volts or more can be tied to insulators, and other similar work accomplished with apparently no greater hazard than accompanies the handling of ordinary 2,300-volt circuits with the protection afforded by insulating gloves and other comparatively thin insulating guards.

Exact distances are mentioned in the table of this rule, although it will, of course, usually be impossible to gauge the distance, except approximately with the eye. Personal judgment, therefore, must be relied on to a large degree, and the distances specified are intended to be reasonable where considerable care is exercised to avoid slipping or inadvertent movement, but will, under certain circumstances, still be insufficient. (See rule 114.)

It is the general experience that the forming of safe habits soon results in involuntary carefulness and will minimize loss of time.

D. Requirement for two workmen.—See discussion of rule 411, B.

E. When to kill parts.—When it is for any reason impracticable to use the precautions given in A, B, and C above for handling live parts, work should not be done unless the lines are killed, and then these precautions are no longer necessary. In order to be sure that parts normally alive are actually killed and will remain so until the necessary work has ceased, the procedure given in rule 423 should be carefully followed. In this way dangerous mistakes and misunderstandings will be avoided.

F. Opening and closing switches.—Frequently operators test the opening of a switch by pulling it a short distance from the contacts. By this operation a mistake may be corrected, and the operator may be able to close the switch again before he is burned by an unexpected arcing, which the opening will not safely interrupt.

G. Work from below.—Usually work on equipment is preferably done from below, since a slight shock will tend to throw the body away rather than upon the live parts. There are, of course, cases where, because of congestion of live parts or other obstructions below the live parts on which work must be done, it is necessary that work be done from above the live part. Under such circumstances adequate covers must be used and additional precautions against falling must, of course, be taken to obtain safety comparable with that where work can be done from below.

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H. Attaching connecting wires and grounds.—One class of electrical injuries which may be entirely avoided is that caused by handling loose conductors carelessly or unnecessarily near to exposed live parts. The use of measuring tapes and ropes having metal threads woven into the strand is dangerous and may be entirely avoided by moderate care on the part of workmen in inspecting such tapes and ropes before using. For ladders see discussion of rule 420, I.

When necessary to connect a dead circuit or equipment to a live circuit, the connection should first be entirely completed, except the actual tap to the live circuit, so that loose connecting wires are dead as long as possible rather than alive by connecting them first to the live circuit.

I. Handling series circuits.—An occasional source of injury is the introduction of the body into a series circuit, as at the secondary terminals of an instrument transformer or at an arc lamp, by contact with the two ends of a circuit which has been carelessly opened without bridging across the opening. Frequently the body does not become part of such a circuit, but the careless opening causes serious arcing at the point of open circuit, and this has been concerned in a number of more or less serious burns.

High-voltage series circuits, such as arc-light circuits, also present hazard through the high voltage between some of their parts and the ground. It is sometimes necessary for safety not only to close the circuit across a device which is to be worked on but to actually disconnect the device from the circuit before touching the device.

423. Killing Equipment or Lines.

The careful procedure given in this section for making certain that lines are actually killed and will remain so while workmen are to work upon them with this assurance, seems fully warranted by a careful study of the various more or less complete procedures which have been adopted by numerous utilities as well as by study of the accidents which have occurred by lack of sufficient understanding between the different parties involved in the killing of lines and equipment. Especially where the lines are extended or are fed from more than one source, opportunity for mistakes and danger to workmen becomes serious where a definite procedure is not invariably followed.

It should be noted that the procedure, however, is considerably shortened and to some extent simplified in those systems where, because all lines are fed from a single station or for other sufficient reason, the chief operator himself operates and tags the switches for the protection of workmen, as noted in rule 423, A.

424. Making Protective Grounds.

The requirement that an effective ground connection be made before contact is made between the grounding device and the wires, is made with full consideration of the fact that such ground connections will be of greater or less actual resistance according to the local conditions.

C. Test of circuit.—In practically all stations it is possible to readily determine which circuits, conductors, or pieces of apparatus are made dead when a particular switch is opened. The operators are or should be familiar with the wiring of the station, and, in addition, the various switches and circuits should be properly identified. A diagram of connections is of great assistance in this connection, but care should be taken to indicate any changes in connections as soon as they are made, as otherwise the diagram would defeat the purpose for which it was intended.

There are many large or old stations, however, which contain very complicated wiring which is so protected and covered or buried that it is extremely difficult to trace. In such stations it is not wise to depend entirely on the memory or knowledge of an individual. In some cases, on interconnected systems, the circuit under consideration may be fed from another source, which is out of the direct control of the operator. The circuit may be crossed with other circuits because of a storm or accident. It is therefore very desirable to have some ready means for determining whether or not a line is alive before applying a protective ground.

Many devices have been suggested and are in use to a limited extent for testing circuits or apparatus to show the presence of voltage. The original endeavor was to make such a test without actually touching the part. However, such devices which have so far been developed have the disadvantage that they are not positive in action. An indication of a dead circuit may also mean that the device is defective. For instance, the potential transformer, exploring coil, Geissler tube, and electroscope methods, at present in use, all are negative in operation. The switch-stick method, which indicates a live circuit or part by the charging current which flows to a metal object supported on an insulating handle, will generally be satisfactory on the higher voltages, although the indication is not always uniform and may even be practically invisible and soundless.

The electrostatic lightning arrester, which is generally available for use, offers a sure and safe method, as a live line will produce the usual indication on the horn gap during charging operations.

One company has developed what is termed the bomb-fuse method which is positive in action when properly used. It, however, is not recommended for use on voltages higher than 15,000. It employs a fuse in series with a limiting resistance connected to ground and to an insulated conductor terminating in a metal tip supported by an insulating handle. The fuse is tested by means of a lamp before and after testing for voltage, thus insuring a positive test should the fuse not blow. On very high voltages, however, the use of such a method might prove very dangerous.

E. Removing grounds.—In removing the ground connection, the necessity for keeping it in contact with the effective ground until all the connections with the normally live parts have been removed must be very well understood. Even the charging current of an otherwise dead line might, if the connection to the ground were first removed, be found sufficient to cause injury to the workman making this mistake, and serious injuries from this cause have in fact occurred.

Sec. 43. SUPPLY SYSTEMS—RULES FOR EMPLOYEES DOING SPECIALIZED WORK

This section is intended as detailed rules to special classes of employees, and it is believed that the rules as worded are, in general, sufficiently simple and clear and detailed to make unnecessary any considerable discussion of them.

430. Supply Stations amd Switchboards.

B. Care about machines.—The necessity for employees to carefully mark starting devices of machines about which they are working while these machines are at rest is so great that in many large industrial establishments more elaborate precautions are taken than those specified in the rule. Many such establishments require the use of locks on the starting devices, in addition to tags. With some utilities a mode of procedure very similar to that given in rule 423 for the killing of live parts is followed in the killing of normally moving parts before workmen are permitted to work thereon while the equipment is idle.

C. Care about live or moving parts.—The lack of sufficient marking on a section of a switchboard or on bus compartments has sometimes been the cause of injury by reason of employees mistakenly making contact with live parts on adjacent panels or in adjacent compartments. Careful tagging will tend to obviate such dangers.

433. Overhead Lines.

B. Testing structures before climbing.—See discussion of rule 451, A.

C. Use of pole steps.—See rule 451, B.

J. Stringing lines.—See rule 451, G and discussion.

436. Underground Lines.

C. Testing for gas.—See discussion of rule 452, B.

E. Avoiding flames.—See discussion of rule 452, D.

Sec. 44. COMMUNICATION SYSTEMS—RULES FOR EMPLOYERS

440. Distribution and Enforcement of Rules.

See discussion of rule 410, A.

441. Address List and Emergency Rules.

In the preparation of address lists the accessibility of physicians, ambulances, and hospitals will be given consideration, and preferably the office and home hours of physicians should, where practicable, be noted, so that delays in emergencies may, as far as practicable, be avoided. See discussion of rule 410, C.

442. Instructing Employees.

See discussion of rule 410, D.

443. Qualification of Employees.

Any person addicted to the use of intoxicants should not be considered a desirable employee. See discussion of rule 410, E.

444. Protective Devices.

See discussion of rule 411, F.

Sec. 45. COMMUNICATION SYSTEMS—RULES FOR EMPLOYEES

450. General Precautions.

A. Heeding warnings, warning others.—See discussion of rule 420 B.

B. Inexperienced employees.—See discussion of rule 420 C.

C. Electrical supply equipment or wires.—See discussion of rules 420 B, F.

D. Safe supports and safety belts.

1. *Safe supports.*—The employee should first assure himself that the ladder is strong enough to support his weight and then that it is so placed that it is not likely to slip or topple over. Standing upon a ladder with both feet upon one rung is usually bad practice.

Before being used, ladders should be inspected for spreading of sides, loose screws, weakened steps, defective braces, etc. Leaning unduly on one side of rolling ladders should be avoided, and handrails should be used where provided.

When it is necessary to rest the foot of the ladder on a smooth surface, such as a cement or flagstone pavement, asphalt street, etc., the employees should see that the base of the ladder is held in such a manner as to prevent slipping. (See also discussion, rule 420, I.)

Under no conditions should a stepladder in poor condition be used. Before mounting care should be taken to see that this type of ladder is fully opened, resting firmly on the four legs, and that the locking device is in place. A stepladder shall not be used by leaning it against the wall, unless a person is stationed at the bottom to brace it.

2. *Safety belts.*—When an employee finds a belt to be defective, he should immediately exchange it for a serviceable one.

E. Duties of foreman.—See discussion of rule 421, B.

F. Handling live parts.—See discussion of rule 422, A.

I. Battery rooms.—The proper tools and utensils should be used in conveying electrolyte to and from batteries and in removing sediment, in order to avoid splashing or spilling of the liquid.

In mixing electrolyte, water should never be poured into concentrated acid. The acid should always be poured slowly into the water to prevent dangerous spattering.

451. Overhead Lines.

A. Precautions to be observed before climbing structures.—Cedar poles may be faulty, due to hollow heart or rot, the latter, in general, beginning at and extending upward from the ground line. The existence of hollow heart may be determined by rapping the pole with a heavy object and probing it with a stocky screwdriver or similar tool at least at three points on its circumference. The existence of rot at or above the ground line can be determined by inspection.

Chestnut poles are not subject to hollow heart, and rot does not, as a rule, extend above the ground line. In testing chestnut poles it is therefore necessary that an inspection be made extending from the ground line to at least 6 inches below the ground line wherever this is feasible. In city work on paved streets or walks, or at any time when the ground is frozen and inspection below the ground line is not feasible, the pole may be tested by rocking or shaking.

If these tests leave any doubt as to the ability of the pole to withstand the employee's weight, even though no change is to be made in the strain on the pole before it is climbed, the employees should see that it is guyed or otherwise suitably braced.

G. Stringing wires.—Communication wires being strung near supply lines should not be touched with the bare hands. Suitable rubber gloves should always be worn.

In pulling the communication wires over electric light, power, or other foreign wires, the hand line should at all times be kept sufficiently taut to prevent the communication wire from coming into contact with the foreign wires.

In throwing the hand line over the foreign wires, pliers, connectors, or other tools should not be used as a weight. The end of the hand line should be carried in such a manner that it will serve as a weight.

The man at the reel should not only wear rubber gloves, but, as an additional precaution, should stand on a dry board, wear rubber boots, or otherwise insulate himself.

If it is necessary to station a man either on the pole or on the ground to guide the wire, this man also should wear rubber gloves and should take such precautions as are necessary to keep himself clear.

Poles which are safe when the tension of the wires or cables in each direction is balanced, and thus serves to support them, are frequently unsafe in case all or some of the wires or cable on one side are removed, unless the unbalanced tension thus caused is equalized by a guy or brace. Under these conditions, if all the attachments are removed, the pole may first have to be guyed or held in all directions. If the tension is removed from one side only, temporary guying on one side may be sufficient.

452. Underground Lines.

B. Testing for gas.—Before entering a manhole a test should be made for the presence of gas. Some gases, however, and particularly natural gas, can not be detected by odor. In natural-gas districts a test should be made by means of an approved safety device.

Any indication of the presence of illuminating gas or that used for ordinary domestic purposes should be reported to the local gas company. A manhole should never be entered until it has been freed from gas. Ventilation of manholes may be provided by one or all of the following methods:

1. By hanging a strip of canvas about 2 feet wide from the top of the manhole guard within the manhole opening, in such a manner as to deflect a current of air into the manhole.

2. By removing the covers of adjacent manholes (unless the ducts in the manhole are plugged).

3. By forcing a current of fresh air into the manhole by means of a blower. The nozzle of the hose connected to the blower should be placed near the floor of the manhole, so as to force the gas up and out of the manhole opening.

D. Avoiding flames.—Gas soldering furnaces or wax-pot furnaces shall be lighted immediately after the gas is turned on, so as to prevent an accumulation of gas which may cause an explosion. When lighting a furnace, the head shall be kept well away from the furnace. In handling hot wax or paraffin care shall be used to avoid splashing or spilling.

Part 5.—RULES FOR RADIO INSTALLATIONS

Sec. 50. SCOPE

500. Scope.

Equipment used in connection with radio apparatus that is connected to electric lighting and power-supply circuits should be installed, in so far as the conductors connected to these circuits are concerned, in accordance with the rules of part 3. Underwriters Laboratories (Inc.) maintain a list of radio equipment approved under their standards for attachment to lighting and power circuits.

These rules are not intended to apply to radio installations on shipboard or on aircraft.

Sec. 51. CLASSIFICATION OF RADIO STATIONS

510. Classification of Radio Stations.

B. Transmitting stations.—This classification of transmitting stations is designed only to clarify the application of rules following in this code. An equivalent definition of medium-power transmitting stations is as follows:

2. *Medium power.*—Transmitting stations to which the power supplied is between 100 and 1,000 watts with voltage not exceeding 2,000, or to which the power supplied is less than 100 watts with voltage between 400 and 2,000.

As to a comparison of those rules of the National Electrical Code that have an application parallel to these rules, it has been interpreted by some that the National Electrical Code covers only such transmitting stations as are classified in this code as of low and medium power.

Sec. 52. ANTENNA AND COUNTERPOISE INSTALLATION

520. Application of Rules.

Antennas used for coupling radio apparatus with line conductors are not included in requirements here given for antennas and counterpoise wires. The rules are also not intended to apply especially to portable antennas, as used upon vehicles of transportation, such as automobiles or aircraft. The rules do not apply to antennas on shipboard.

The Aeronautical Safety Code, A. E. S. C. D 1–1925, includes requirements for marking high radio station towers by black and white stripes for day visibility and for surmounting the tower with a light at night. Additional rules concerning the location of radio towers with respect to airdrome buildings and landing areas are also included.

The method of installation of antennas on airplanes to prevent interference with flight, to safeguard the occupants of the airplane against shock from transmitting antennas, and to facilitate their use is also treated in the Aeronautical Safety Code.

521. General Requirements.

Antenna conductors have inherently the status of aerial electrical conductors. Those carrying voltages below 400, with a power capacity of 100 watts or less, partake of the nature of communication conductors, and those with power or voltage exceeding these limits partake of the nature of supply conductors (see Definitions). Under conditions usually met, however, the rules of this part completely cover the installation of antennas, and it is only under conditions not described in part 5 or infrequently met with that resort must be taken to the rules of part 2.

522. Locations to be Avoided.

Antennas located in any of the situations enumerated introduce material hazards. If necessarily occupying locations ordinarily to be avoided, antennas are expected to meet strength and clearance requirements in addition to the requirements for ordinary construction. For certain of the more frequent conditions the requirements will be found in rule 524, otherwise in part 2 of the code.

523. Ordinary Construction of Antennas.

A. Antenna conductors.—All antenna conductors should be of sufficient size and durability to withstand ordinary weather conditions.

C. Antenna supports.—Antenna supports on roofs should be so stable that the breaking of the antenna wires, such as in a sleet storm, will not make likely the falling of the support, possibly from the roof to the ground. Chimneys are not ordinarily designed to withstand large horizontal forces and may be made unsafe by application of the tension of an antenna wire. A wooden pole mounted near the chimney and fastened to it, sometimes extending above the top of the chimney, is especially to be discouraged. Metal poles extending more than 10 feet above the supporting building add to the lightning hazard of the building unless effectively grounded.

D. Attaching antennas to supports.—In the erection of some broadcasting antennas a weak link has been installed between the attachment to the support and the antenna conductors themselves. This link is designed to break before the antenna conductors or the fastening to the support. This rule prohibits the insertion of this weak link unless additional means are provided to support the antenna with at least the specified minimum clearance above ground after the breaking of the link. The attachment to the support should be stronger than the antenna conductors.

E. Minimum clearance above ground.—The clearances given in Table 2 are considered to be the minimum necessary for free movement of persons or vehicles likely to come underneath. Large, flat roofs may be considered to come under the designation "Spaces or ways accessible only to pedestrians." Particular care should be taken when erecting antennas over roofs to allow ample clearance under them for the freedom of firemen in case of emergency. An increase in clearances above ground corresponding to an increase in span length beyond 150 feet is specified to insure the maintenance of the minimum clearances of Table 2 under conditions of ice loading or high summer temperature.

F. Minimum clearances below supply and communication conductors.—Crossings between antenna wires and supply or communication conductors are always to be avoided if practicable. In case a crossing is necessary, it is greatly preferable to carry the antenna wires under the supply or communication conductors. The minimum clearances given in Table 3 presuppose substantial antenna supports and wires and careful erection of the antenna wires so that no accident will bring them closer than the clearances specified. The erection and maintenance of antenna wires at crossings with supply conductors has been a much too frequent source of serious accident. Accidental contact between the antenna wires and the utility conductors may entail serious consequences.

524. Special Construction of Antennas.

Where antennas conflict with or cross over communication or supply conductors or railways, they present the same hazards as other conductors in the same situation.

The construction of antennas crossing or conflicting with other electrical lines or railways should be, in precautions and reliability, commensurate with the hazards introduced, including electrical shock to those installing and using the radio apparatus and the interruption of and interference with the services of such utilities.

The crossing or conflict of antenna wires with low-voltage conductors and service conductors does not introduce hazards of the same degree of severity as similar situations with respect to higher-voltage line conductors. These situations are also more frequently met and for average conditions are completely covered by rules 524, B, and C, without reference to part 2. For all cases where antennas are involved with electrical lines or railways not described in rules 524, B, and C, resort must be had to the rules of part 2 applying to similar situations. In these special cases antennas of receiving stations and low-power transmitting stations have the status of communication conductors (see definitions) and those of medium and high-power transmitting stations the status of supply conductors.

Where antennas do cross or conflict with conductors of other overhead electric systems, it is especially important that the protective grounding conductor and its connection to ground be effective. The grounding conductor should have a size and current-carrying capacity that will insure the fusing of the lead-in conductor before the grounding conductor under conditions of high-current discharge that may accompany accidental contact with a supply wire. The ground connection should also have a low enough resistance and adequate current capacity to avoid dangerous potentials above ground in the radio apparatus under conditions of accidental contact with supply wires.

525. Guarding of Antennas.

Inaccessibility of antenna conductors for transmitting stations may be attained by fences, guardrails, or more proximate inclosures, or by elevating the conductors above the reach of persons. Towers carrying antenna conductors of more than 300 volts to ground are preferably either guarded against unauthorized climbing or provided with warning signs. Fences or inclosures may be used for guards, or when the steel latticing of the tower is not sufficiently close to serve as steps guarding may be accomplished by placing the lowest step provided for climbing not less than 6.5 feet above ground. A small block or other possible foot rest not less than 3.5 feet above the ground may, however, be used to facilitate reaching the first step.

Sec. 53. LEAD-IN CONDUCTORS

530. Application of Rules.

High-power transmitting stations, both by reason of the usual qualifications of the operating personnel and the amount of electrical power utilized, are considered to fall logically under the classification of power stations and as such, rules governing their installation and maintenance will be found in part 1.

As regards ground connections, see 560, the rules in part 5 may be sufficient for high-power transmitting stations.

533. Installation of Lead-In Conductor.

C. From building entrance to set.

1. *Receiving stations.*—Because of the possibility of receiving sets becoming unexpectedly alive due to accidental contacts between antennas and electric supply wires, or due to inductance from lightning, it is recommended that lead-in wires from the building entrance to the receiving set be insulated. This insulation should be at least equivalent to that afforded by rubber-covered wire approved by Underwriters Laboratories (Inc.) for 0–600 volts (type R). This will afford, in connection with the protective device and the protective ground, a reasonable fire and safety precaution.

Sec. 54. CONSTRUCTION AT BUILDING ENTRANCE

542. Creepage and Air-Gap Distance.

Transmitting apparatus using undamped waves are frequently also known as continuous-wave sets, and the 3-inch creepage distance is intended to apply to such sets.

Sec. 55. PROTECTIVE AND OPERATING GROUNDING CONDUCTORS

Ground connections are made for two purposes. Radio apparatus is frequently connected between an antenna and ground either by insertion directly in the circuit or by inductive coupling. Radio waves when intercepted by the antenna will cause currents to flow to and fro between antenna and ground. It is these currents which operate the receiving apparatus.

In addition to this operating function, a ground connection affords protection by controlling the potential of the equipment and antenna and by offering a path to ground for any discharge from the lightning arrester. The rules are concerned with the latter or protective grounding connection being adequate, but for receiving stations makes no requirement for the operating grounding conductor, which is not considered to involve a hazard.

In practice, a single grounding conductor usually serves for both purposes, and in that case it must meet the requirements for the protective grounding conductor. This must be as large as the lead-in conductor and must be protected where exposed to mechanical injury. The purpose here is to maintain the connection intact and to insure that the grounding conductor will be able to carry any discharge of lighting which the lead-in conductor is able to carry.

It should be emphasized that the protective grounding conductor or combined protective and operating grounding conductor should preferably be of a higher current-carrying capacity than the lead-in or "down-lead." The reason for requiring the protective grounding conductor to be guarded against mechanical injury and for here recommending that it be of a larger current-carrying capacity than the lead-in is to be sure that the protective ground connection when needed will be intact and will not be fused by the current it is discharging, and thus leave the set with a high potential above ground in case of an accidental cross with other wires.

Sec. 56. GROUND CONNECTIONS

The same principles apply in making protective ground connections for radio equipment that apply in other cases, and such requirements are fully set forth in section 9. Section 56 repeats briefly those requirements of section 9 which are particularly applicable to a radio installation.

As pointed out in the discussion of section 9, an underground system of water piping gives the best ground connection. When such a system is not available, resort must be had to artificial grounds or to some other metallic structure which is embedded in the earth. Gas piping is not recommended for grounding purposes but it is not prohibited, and cases will arise where it constitutes the most satisfactory available ground. Care should be taken to connect an effective bond around any insulating joints or electrical discontinuity of the gas-piping system that may occur, especially near the meter location. This subject is more fully discussed under section 9.

Sec. 57. PROTECTIVE DEVICES

571. Lightning Arrester.

Lightning arresters are required only on lead-in conductors from aerial antennas of receiving stations. Lightning arresters may also be used in connection with transmitting stations. For receiving stations and low-power transmitting stations the lightning arrester should operate at a potential of 500 volts or less. For medium-power transmitting stations, where the voltage of the power supplied exceeds 400 volts, it will be necessary that lighning arresters have a spark-gap voltage higher than 500.

C. Location.—Lightning arresters when used in connection with transmitting stations of low or medium power will be expected to comply with the requirements of paragraph C, although the use of lightning arresters in these situations is not required, and paragraph B is consequently not applicable.

572. Antenna Grounding Switch.

For transmitting stations operating at very high frequency it may be necessary from practical considerations to use Pyrex glass for the switch base or to resort to a flexible grounding lead and substantial clamp in lieu of the double-throw switch. If the grounding clamp is sufficiently substantial and the lead of at least as large current-carrying capacity as the grounding conductor, it may be the equivalent from a safety point of view of the grounding switch.

Sec. 59. BATTERIES

591. Care in Handling.

The seriousness of shock depends on the current and the part of the body through which it passes rather than directly upon the potential difference. A current as small as 0.1 ampere if it passes through the vital part of the body; that is, the part in which the heart is located, generally causes a serious nervous disorganization or death. Involuntary muscular contraction of the parts of the body affected may be expected from currents of from 0.005 to 0.020 ampere, and currents above these values are generally considered unsafe. When current passes through the vital part of the body, usually the circuit is from hand to hand or hand to foot. With the best of connections, with the skin wet, the resistance from hand to hand or hand to foot is seldom less than 500 ohms. With accidental connections, this resistance is usually from 5,000 to 50,000 ohms. Consequently, while severe shock may result from potential differences as low as 25 volts, there is very little danger from potential differences less than 100 volts. In cases in which parts of the circuit are at potentials with respect to ground of more than 100 volts, they should be insulated or shielded so as to prevent accidential connections being made between them and ground by means of the body.

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