DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 54

NATIONAL ELECTRICAL SAFETY CODE

FOR EXAMINATION, TRIAL, AND CONSTRUCTIVE CRITICISM

[2d Edition]

Issued November 15, 1916

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NATIONAL ELECTRICAL SAFETY CODE

INTRODUCTORY PART

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INTRODUCTION

After three years of continuous study and investigation and the thorough revision of successive preliminary drafts submitted for discussion and criticism, the Bureau of Standards presents herewith the completed text of the National Electrical Safety Code for examination and use on trial. In addition to two introductory sections giving definitions of terms and rules for the grounding of apparatus and circuits, the code consists of four principal parts, as follows:

1. Rules for the installation of machinery, switchboards, and wiring in central stations and substations.

2. Rules for the construction of overhead and underground lines for the transmission and distribution of electrical energy and intelligence.

3. Rules for the installation of electrical apparatus and wiring in factories, residences, and wherever electricity is utilized for light, heat, or power.

4. Rules for safeguarding employees when working on or near electrical machines or lines.

HISTORY

Part 4 was first published in August, 1914, as Circular No. 49 of the Bureau, and after revision with the cooperation of the accident prevention committee of the National Electric Light Association, republished in May, 1915, as a second edition of that circular. The rules have been used by a large number of companies during the 15 months since their second publication, and the present edition has been thoroughly revised in the light of considerable experience in actual use.

The other three parts of the code were printed as Circular No. 54, of the Bureau, in April, 1915, and have been very thoroughly studied and developed since then. The complete code is now offered for careful study and use in practice, with the expectation that it will be revised again within a year or two, in the light of experience gained in such practical use.

Each of the principal parts of the code is followed by a discussion of its provisions intended to make clearer the meaning and application of the rules. These discussions, which will be revised in the successive future editions of the code, have been prepared with the expectation that they will be useful to companies and individuals in complying with the rules and to commissions and municipalities in administering the code.

NATION-WIDE COOPERATION

The Bureau has had the cordial cooperation and assistance of many State industrial and public-service commissions, municipal electrical inspectors, engineers of operating and manufacturing companies, committees of engineering societies, and representatives of the fire and casualty insurance interests and of the electrical workers. Without such cooperation the work would have been impossible. With it progress has been rapid, considering the magnitude of the task, and the interests of all concerned have been conserved. It is hoped that the completed code will receive the very general support of all those affected by it.

This electrical safety code, more particularly part 3 on electrical utilization equipment, runs parallel with the National Electrical Code (for fire protection), which is revised every two years by the Electrical Committee of the National Fire Protection Association. As it was desirable that there be no conflict between them, and as little overlapping as possible, the Bureau came to an early understanding with the Electrical Committee as to the relations between the two codes. The Bureau offered originally to cooperate with the Electrical Committee in framing safety rules to be incorporated in the present electrical code; but at a conference with representatives of the National Fire Protection Association it was found to be the general desire to keep the safety rules and the fire-prevention rules as distinct as possible, and have these two parts of a complete electrical code parallel and separate instead of interlaced in such a way that they could not be distinguished. This separation simplifies their preparation, and also their administration, as in some cases administrative bodies concerned with one of the codes will not be concerned with the other.

An understanding was accordingly reached between the representatives of the Bureau of Standards and the representatives of the National Fire Protection Association that the Bureau of Standards should take the responsibility of preparing a National Electrical Safety Code, with the cooperation of the National Fire Protection Association and other organizations, and that such changes as seemed necessary and could properly be made in the fire code to avoid conflicts or overlapping with the new safety code would be made. In return the Bureau of Standards was to cooperate with the National Fire Protection Association in the revision of the fire code. In accordance with this understanding a committee was appointed to confer with representatives of the Bureau, and together they went through the fire code and made certain recommendations as to changes (which were substantially all adopted at the next meeting of the electrical committee) and then went through the preliminary draft of the safety code and made many valuable suggestions for its improvement. At a subsequent meeting this committee carefully criticized a later draft of the code and suggested further improvements.

A large number of formal and informal conferences have been held by the representatives of the Bureau with representatives of

State commissions, engineers of operating and manufacturing companies, and others, in which the rules of the several parts of the code were critically examined and when necessary amended. Formal conferences usually attended by from 25 to 50 engineers and other representatives of the interests concerned have been held in Boston, Schenectady, New York, Philadelphia, Washington, Atlanta, Columbus, Chicago, St. Louis, Denver, Boise, Los Angeles, San Francisco, Portland, and Seattle. Informal conferences have been held in many other places in all parts of the country. Many differences of opinion, of course, were expressed in these conferences regarding certain rules of the code, but many of these differences were removed or modified in the course of the discussion, and it has been possible to secure approval of nearly all the rules by a very large majority of those participating in the conferences.

NEW YORK CONFERENCE

The New York conference, held in the autumn of 1915, was attended by over a hundred persons, chiefly representatives of the public utilities, including some of their ablest engineers. This conference was held at the request of the American Institute of Electrical Engineers, the National Electric Light Association, and the Association of Edison Illuminating Companies. The meeting continued for two weeks, a very thorough study was made of the entire code, and important modifications were made in some of the rules. At the conclusion of the conference it was felt by most of the delegates present that the code so modified met the various criticisms in a generally satisfactory manner, and that it was substantially ready for printing and adoption for trial use, either by administrative bodies or by utility companies who would use it voluntarily.

However, certain features in part 2 on line construction remained somewhat unsettled, due to conflicting statements of fact by various engineers or to insufficient data available at the New York conference. These matters, which were confined principally to the questions of safe practice in conductor sags and of maximum safe wire loads for steel and wood pole lines, were left to the further study of the Bureau. These and some allied subjects received the careful attention of the Bureau engineers and many inspections in the field, as well as much correspondence resulted in revision of the rules on these subjects to represent good present practice, although differing considerably from some proposals which had previously been placed before the Bureau.

One of these proposals was for smaller sags of conductors than the Bureau considered practicable. To test the question, the Bureau has recently made inspections of lines and measurements of sags in 15 cities in heavy-loading districts between Maine and Minnesota. The average value of the sags found in these measurements agrees very well on the average with the values specified in the tables of the code, although the sags for the larger sizes were frequently larger than given in the tables, and in many cases the sags for the smaller sizes of wire were also larger than called for by the code. Further inspections and measurements will be made during the coming year, and the sag tables will be revised as experience shows it is necessary. In such revision some sags may be increased and others decreased. At the present time, however, the values given certainly do not appear to be too large.

GENERAL CONFERENCE AT CHICAGO

At the general conference of all interests, held in Chicago May 29 and 30, 1916, State and municipal administrators were largely represented as well as utilities, manufacturers, and others interested. The Bureau reported the changes and developments in the code since the New York conference and invited expressions of opinion of the code as to its practicability and adequacy for general use on trial. There was substantial agreement of the delegates representing all classes of utilities and administrative agencies concerned with the code that it was ready for publication and submission for use on trial as proposed. Some apprehensions were expressed by some utility representatives regarding the effect of application of the code rules by administrators unfamiliar with its provisions or unwilling to modify the rules as is their stated intent. The administrators, however, stated clearly their wish to begin the application of safety requirements in a reasonable manner, as indicated in the rules on the scope and application of the code.

It was brought out in the Chicago conference that the code rules have been considerably developed in the course of the very thorough study and discussion that has been given to them during the 14 months since the first printed edition, so that the code does not appear as simple as the earlier edition. These additions have frequently been made at the request of conferees. Sometimes alternatives or exceptions have been written plainly into the rules instead of leaving them to be inferred from the form of the general rule. The rules have been made to recognize differences in climate and in density of population where these cause a difference in degree of hazard, as is particularly the case with overhead lines. No previous set of rules has definitely recognized these differences in hazard. This treatment of the subject has added a considerable amount of detail to the rules, but none of the many conferees consulted have recommended brevity at the expense of clearness and reasonableness, and the detail will tend to prevent misunderstandings between administrators and those to whom the rules apply. The general opinion was expressed by the delegates present that the proper methods had been pursued in securing the practicability and general adequacy of the code as far as could be done prior to its actual adoption and trial.

The proceedings of this general conference are being published, since they are of much public interest. They include a much more circumstantial account of the steps taken in the development of the safety code than can be included in a brief introduction.

TRIAL USE RECOMMENDED

The Bureau recommends that the code be adopted at present only for use on trial. That is, that utilities and others to whom its provisions apply be asked to study it and use it as far as they can reasonably, and report to the proper administrative bodies any respects in which they can not comply to the extent intended in the code. The code will be revised in a year or so in the light of such experience, and may then be adopted more formally and made mandatory to a greater degree than would be reasonable at present.

There can be no doubt as to the desirability of having a single code, prepared through the fullest cooperation of all the interests concerned and developed through the freest possible discussion and criticism of proposed rules. It is believed that the Bureau of Standards occupies a peculiarly favorable position to undertake the preparation and subsequent revision of such a code. With an experienced staff of engineers who can devote their time exclusively to the work and who can personally keep in touch with the electrical interests all over the country by frequent visits to manufacturing plants and operating stations, as well as by attendance upon meetings of engineering societies and their technical committees and conferences with operators, workmen, inspectors, and the State commissions, it is believed that we shall obtain full information on the subjects concerned and a broad and unbiased view, and that the rules will be better and more acceptable than if prepared by commissions separately or by some less representative single agency. The Bureau will also be of service in securing a more uniform interpretation and administration of the code than would be possible without such a coordinating agency.

Criticism of the rules contained in this publication, and suggestions for their improvement, either by way of changes or additions, is invited. Before offering such criticism, however, it is hoped that the statement concerning the plan and scope of the code will be read, as well as the discussions on the rules. The intent of the rules will thus be better understood and criticism will be correspondingly more valuable.

The thanks of the Bureau are extended to the very large number of persons and associations who have so willingly assisted in the discussion and revision of the code. It is hoped that this cordial cooperation may be continued and that the code will be found both adequate and reasonable, and so acceptable and useful as to justify the large amount of time and labor given to it by our conferees.

S. W. STRATTON,
Director.

JULY 24, 1916.

Section 1.—DEFINITIONS OF SPECIAL TERMS

ALPHABETICAL LIST OF DEFINED TERMS

The following definitions give the meanings of some of the terms occurring in these rules. Terms not defined will be understood to have their usual meanings.

1. **Electrical supply equipment** means equipment which produces, modifies, regulates, controls, or safeguards a supply of electrical energy. Similar equipment, however, is not included where used in connection with signaling systems under the following conditions:

(*a*) Where the voltage does not exceed 150.

(*b*) Where the voltage is between 150 and 400 and the power transmitted does not exceed 3 kilowatts.

2. **Electrical supply station** means any building, room, or separate space within which is located electrical supply equipment and which is accessible as a rule only to properly qualified persons.

This includes generating stations and substations and generator, storage battery, and transformer rooms, but excludes manholes and isolated transformer vaults on private premises. (See definition 46.)

3. **Electrical supply lines** means those conductors and their necessary supporting or containing structures which are located entirely outside of buildings and are used for transmitting a supply of electrical energy.

Does not include open wiring on buildings in yards or similar locations where spans are less than 20 feet, and all the precautions required for stations or utilization equipment, as the case may be, are observed.

Railway signal lines above 400 volts to ground are always supply lines within the meaning of these rules, and below 400 volts may be considered as supply lines, if so run and operated throughout.

4. **Signal lines** means lines for public or private signal or communication service and devoted exclusively to the transmission of signals or intelligence, which operate at not exceeding 400 volts to ground or 750 volts between any two points of the circuit, and the transmitted power of which does not exceed 150 watts. Below 150 volts no limit is placed on the capacity of the system.

Telephone, telegraph, messenger-call, clock, fire, or police alarm, and other systems conforming with the above are included.

Lines used for signaling purposes, but not included under the above definition, are considered as supply lines of the same voltage and are to be so run.

Signal lines not for public use coming under the above definition may be run and operated as supply lines if desired, and if consistently so run.

5. **Utilization equipment** means equipment, devices, and connected wiring, which utilize electrical energy for mechanical, chemical, heating, lighting, testing, or similar purposes and are not a part of supply equipment, supply lines, or signal lines.

6. **Voltage or volts** means the highest effective voltage between the conductors of the circuit concerned, except that in grounded multiwire circuits, not exceeding 750 volts between outer conductors, it means the highest effective voltage between any wire of the circuit and the ground.

In ungrounded, low-voltage circuits, voltage to ground means the voltage of the circuit.

When one circuit is directly connected to another circuit of higher voltage (as in the case of an autotransformer), both are considered as of the higher voltage, unless the circuit of lower voltage is permanently grounded. Direct connection implies electrical connection as distinguished from connection merely through electromagnetic or electrostatic induction.

7. **Circuit** means a conductor or system of conductors through which an electric current is designed to flow, and connected equipment.

8. **Grounded** means connected to earth or to some extended conducting body which serves instead of the earth, whether the connection is intentional or accidental.

9. **Grounded system** means a system having a permanent and effective electrical connection to earth. This ground connection may be at one or more points.

"Effective," as herein used, means a connection to earth of sufficiently low resistance and high current-carrying capacity to prevent any current in the ground wire from causing a harmful voltage to exist between the grounded conductors and neighboring exposed conducting surfaces which are in good contact with the earth, or with neighboring surfaces of the earth itself, under the most severe conditions which are liable to arise in practice.

10. **Permanently grounded** means such an effective connection to the earth (by use of an underground system of metallic pipe mains or other suitable means), as described in the preceding paragraph.

11. **Current-carrying part** means a part intended to be connected in an electric circuit to a source of voltage. Noncurrent-carrying parts are those not intended to be so connected.

12. **Alive or live** means electrically connected to a source of potential difference, or electrically charged so as to have a potential different from that of the earth. The term "live" is sometimes used in place of the term "current-carrying," where the intent is clear, to avoid repetitions of the longer term.

13. **Dead** means free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth. The term is used only with reference to current-carrying parts which are sometimes alive.

14. **Manual** means operated by personal intervention.

15. **Automatic** means self-acting, operating by its own mechanism when actuated by some impersonal influence; as, for example, a change in current strength. Not manual, without personal intervention. Remote control that requires personal intervention is not automatic, but manual.

16. **Cut-out** means any device, such as a fuse or circuit breaker, by which the electrical continuity of a conductor may be automatically broken by changes in current or voltage.

17. **Switch** means a device for opening or closing or changing the connection of a circuit manually. In these rules a switch will always be understood to be manually operated, unless otherwise stated.

18. **Disconnector** means a switch which is intended to open a circuit only after the load has been thrown off by some other means.

Manual switches designed for opening loaded circuits are usually installed in circuit with disconnectors, to provide a safe means for opening the circuit under load.

19. **Substantial** means so constructed and arranged as to be of adequate strength and durability for the service to be performed under the prevailing conditions.

20. **Qualified or authorized** means properly qualified or authorized to perform specified duties under the conditions existing. Responsibility for the authorization and decision as to the qualifications of employees rests with the employer or his agent.

21. **Guarded** means covered, shielded, fenced, inclosed, or otherwise protected, by means of suitable covers or casings, barrier rails or screens, mats, or platforms, to remove the liability of dangerous contact or approach by persons or objects to a point of danger.

22. **Isolated** means that an object is not readily accessible to persons unless special means for access are used.

23. **Isolation by elevation** means elevated sufficiently so that persons may safely walk underneath.

24. **Exposed** means that an object or device can be inadvertently touched or approached nearer than a safe distance by any person. Objects not suitably guarded or isolated.

25. **Insulated** means separated from other conducting surfaces by a dielectric substance or air space permanently offering a high resistance to the passage of current and to disruptive discharge through the substance or space.

When any object is said to be insulated, it is understood to be insulated in suitable manner for the conditions to which it is subjected. Otherwise, it is, within the purpose of these rules, uninsulated. Insulating covering of conductors is one means for making the conductors insulated.

26. **Insulating** (where applied to the covering of a conductor or to clothing, guards, rods, and other safety devices) means that a device, when interposed between a person and current-carrying parts, protects the person making use of it against electric shock

from the current-carrying parts with which the device is intended to be used; the opposite of conducting.

27. **Explosion proof** (in locations where the presence of inflammable gas makes the atmosphere explosive in character) means that an inclosure will withstand, without injury and without transmitting flame to the outside, any explosion of gas which may occur in the inclosure.

28. **Inclosed** (in locations where inflammable flyings, inflammable dust or explosives are present in dangerous quantities) means that an inclosure will not admit accumulations of flyings or dust, nor transmit sparks or flying particles to the accumulations outside.

29. **Conductor** means a metallic conducting material, usually in the form of a wire or cable, suitable for carrying an electric current. Does not include bus bars.

30. **Line conductor** means one of the wires or cables carrying electric current, supported by poles, towers, or other structures, but not including vertical or lateral connecting wires.

31. **Open lines** means overhead lines not in conduits, and consisting of single conductors or of individual twisted pairs, as opposed to multiple conductor cables.

32. **Service** means the connecting conductors by which a supply of electrical energy is carried from a supply line to the building or premises served.

33. **Lateral conductor** means in pole wiring work, a wire or cable extending in a general horizontal direction approximately at right angles to the general direction of the line conductors.

34. **Vertical conductor** means in pole wiring work, a wire or cable extending in an approximately vertical direction.

35. **Normal sag** means the difference in elevation between the highest point of support of a span and the lowest point of the conductor in the span (or in the curve of the conductor in the span produced), at 60° F, with no wind loading.

36. **Apparent sag of a span** means the departure of the wire in a given span from the straight line between the two points of support of the span, at 60° F., with no wind loading. Where the two supports are at the same level this will be the normal sag.

37. **Apparent sag at any point** means the departure of the wire at the particular point in the span from the straight line between

the two points of support of the span, at 60° F, with no wind loading.

38. **Pole face** means that side of a pole on which cross-arms are attached, or which is so designated by the utilities owning or operating the pole.

39. **Climbing space** means the vertical space reserved along the side of a pole structure to permit ready access for linemen to equipment and lines located on the pole structure.

40. **Lateral working space** means the space reserved for working between conductor levels outside the climbing space, and to its right and left.

41. **Conflicting or in conflict** (as applied to a pole line) means that the line is so situated with respect to a second line (except at crossings) that the overturning of the first line will result in contact between its poles or conductors and the conductors of the second line, assuming that no conductors are broken in either line: *Provided, however,* That lines on opposite sides of a highway, street or alley are not considered as conflicting if separated by a distance not less than 60% of the height of the taller pole line, but in no case less than 20 feet.

42. **Duct** means (in underground work) a single tubular runway for underground cables.

43. **Conduit** means (in underground work) a group of any number of ducts for underground cables.

44. **Manhole** (more accurately termed **splicing chamber** or **cable vault**) means an opening in an underground system which workmen or others may enter for the purpose of installing cables, transformers, junction boxes, and other devices, and for making connections and tests.

45. **Handhole** means an opening in an underground system into which workmen reach but do not enter.

46. **Transformer vault** means an isolated, fireproof inclosure, either above or below ground, in which transformers, and the devices necessary for their operation, are installed, and which is not continuously under attendance during operation.

47. **Reconstruction** means replacement of any portion of an existing installation by new equipment or construction. Does not include ordinary maintenance replacements.

48. **Urban districts** means thickly settled communities (whether in cities or suburbs) where congested traffic often occurs. A highway, even though in the country, on which the traffic is often very heavy, is considered as urban.

49. **Rural districts** means all places not urban, usually in the country, but in some cases within city limits.

50. **Wire gages:** The American Wire Gage (A. W. G.), otherwise known as Brown & Sharpe (B. & S.), is the standard gage for copper, aluminum, and other conductors, excepting steel, for which the Steel Wire Gage (Stl. W. G.) is used throughout these rules.

51. **Switchboard** means a large single panel or assembly of panels on which are mounted (partly on the face and partly on the back) switches, fuses, busses, and usually instruments, and accessible both in front and in rear. Circuits and machinery of relatively large capacity are controlled from such boards.

52. **Panelboard** means a single panel containing busses, fuses, and switches to control lights, fan motors, and similar devices of small individual as well as aggregate capacity, placed in or against a wall or partition and accessible only from the front.

53. **Tags** means "**men at work**" tags of distinctive appearance, indicating that the equipment or lines so marked are being worked on.

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

CONTENTS

RULES COVERING METHODS OF PROTECTIVE GROUNDING

90. Scope of the Rules

The following rules apply to all lightning arrester grounding and to the grounding of all circuits, equipment, or wire runways, when the grounding is intended to be a permanent and effective protective measure. These rules do not require that grounding shall be done, but cover the methods for protective grounding. The rules requiring grounding, in accordance with the methods specified below, are included under parts 1, 2, 3, and 4 of the National Electrical Safety Code.

Other methods of construction and installation than those specified in the rules may be used as experiments to obtain information, if done where supervision can be given by the proper administrative authority.

The following rules do not apply to the grounding of arresters on signal circuits, to the grounded return of trolley or third-rail systems, nor to the grounding of lightning protection wires where these are not connected to electrical circuits or equipment.

91. Application of the Rules and Exemptions

(*a*) The rules are intended to apply to all such installations, except as modified or waived by the proper administrative authority or its authorized agents, and are intended to be so modified or waived in particular cases whenever any rules are shown to involve expense not justified by the protection secured, or for any other reason to be impracticable, or whenever it is shown that equivalent or safer construction can be more readily provided in other ways.

(*b*) The intent of the rules will be realized (1) by applying the rules in full to all new installations, reconstructions, and extensions, except where any rule is shown to be impracticable for special reasons, or where the advantage of uniformity with existing construction is greater than the advantage of construction in compliance with the rules; (2) by placing grounds on existing installations or bringing present grounds into compliance with the rules, except where the expense involved is not justifiable.

The time allowed for bringing existing installations into compliance with the rules will be determined by the proper administrative authority.

(*c*) It will sometimes be necessary to modify or waive certain of the rules in cases of temporary installations or installations which are shortly to be dismantled or reconstructed.

(*d*) In cases of emergency or pending decision of the administrator the person responsible for the installation may decide as to modification or waiver of any rule, subject to review by proper authority.

92. Where Ground Conductor shall be Attached (when Grounding is Required by this Code, or is Installed as a Protective Measure, see rule 304)

(*a*) Direct-Current Distribution Systems.—The neutral of three-wire direct-current systems shall be grounded at one or more supply stations, but not at individual services nor within buildings served. One side of a two-wire direct-current system may be grounded, but at one station only.

In three-wire systems the neutrals entering any junction box should be bonded together, but the box should not be specially grounded. In two-wire systems the grounded side of the circuit should be insulated from ground except at the station ground connection.

(*b*) Alternating-Current Distribution Systems.—All secondary distribution systems shall be grounded at the building services or near the transformer (or transformers) either by direct ground connection (through water-piping system or artificial ground, see rule 94) or by the use of a system ground wire to which are connected the grounded conductors of many secondary mains and which is itself effectually grounded at intervals that will fulfill, for any secondary utilizing the system ground wire, the resistance and current-carrying requirements of rule 96 *a*.

Single-phase, three-wire distribution systems shall be grounded at the neutral conductor. Two-wire, single-phase systems shall be grounded at the neutral point or on either conductor. Two-wire, single-phase and two or three phase systems shall, in general, be grounded at that point of the system which brings about the lowest voltage from ground of unguarded current-carrying parts of connected devices and also permits most convenient grounding.

Where one phase of a two or three phase system is used for lighting, that phase should be grounded and at the neutral conductor, if one is used.

In the absence of direct grounds at all building services, ground connections shall be made to the grounded neutral or other grounded conductor of a secondary system supplying more than one utilization equipment, at intervals that will fulfill the resistance and current-carrying requirements of rule 96 *a*.

Where the secondaries of transformers are supplying a common set of mains the fuses shall be installed only at such points as will not cause the loss of the ground connections after the fuses in the transformer circuits or mains have been blown.

Multiple grounds are preferable in all cases, because of the assurance provided against loss of the protection afforded by the chance disconnection of any ground connection.

Grounds other than the single ground connection at the building service shall not be made to alternating-current secondaries within the buildings served.

(*c*) Lightning Arresters.—The connection to a lightning arrester shall be at such a point that its ground conductor is as short and straight as practicable.

Ground conductors for lightning arresters should not pass through iron or steel conduits unless electrically connected to both ends of such conduits.

(*d*) Equipment and Wire Runways.—The point at which the ground conductor is attached to equipment or wire runways shall, if practicable, be readily accessible.

93. Ground Conductor

(*a*) Material and Continuity.—The ground conductor shall be of copper or of other metal which will not corrode excessively under the existing conditions and, if practicable, should be continuous. Joints shall be so made and maintained as to conform to the resistance and current-carrying capacity requirements of rule 96.

Ground connections from circuits should not be made to jointed piping within buildings, except that water piping outside of meters and beyond any point which is liable to disconnection may be used. (See rules 94 *a*, 95 *a*, and 95 *b*.)

No automatic cut-out shall be inserted in the ground conductor or connection except in a ground connection from equipment where its operation will immediately result in the automatic disconnection from all sources of energy of the equipment so grounded; no switch shall be so inserted except in plain sight, provided with distinctive marking and effectively isolated from unqualified persons. (See also rule 92 *b*, par. 4.)

(*b*) Size and Number.—For grounding circuits the ground conductors shall have a combined cross section (and current capacity) sufficient to insure the continuity of the ground connection and its continued compliance with rule 96 *a*, under conditions of excess current caused by accidental grounding of any normally ungrounded conductor of the circuit. No individual ground conductor for electrical circuits shall have less current capacity than that of a No. 6 copper wire, except that for additional grounds after the first on any circuit, smaller, ground wires may be used, provided that they are in no case smaller than the conductor to which they are attached nor smaller than No. 10 copper.

For lightning-arrester ground connections the ground conductor or conductors shall have a current-carrying capacity sufficient to insure continuity of the ground connection under conditions of excess current caused by or following discharge of the arrester. No individual ground conductor shall be smaller than a No. 6 wire.

For electrical equipment the current-carrying capacity of a ground conductor shall be not less than that provided by a copper wire of the size indicated in the following table. When there is no cut-out protecting the equipment, the size of ground conductor will be determined by the design and operating conditions of the circuit.

Capacity of nearest automatic cut-outs.	Required size ground conductor A. W. G.
200 to 500 amperes	4
100 to 200 amperes	6
30 to 100 amperes	10
10 to 30 amperes	14

In portable cord to portable equipment protected by fuses not greater than 10-ampere capacity a No. 18 ground wire may be used.

(*c*) Mechanical Protection and Guarding Against Contact.—Where exposed to mechanical injury the ground conductor shall be protected by substantial conduit or other guard. Guards for lightning-arrester ground conductors should be of nonmagnetic material unless the ground conductor is electrically connected to both ends of the guard.

If the resistance of the ground connection is in excess of the values in rule 96 for water pipe grounds, the ground conductor, except in rural districts, shall be protected and guarded by being inclosed in insulating conduit or molding to protect persons from injury by coming into contact with it.

Such a high resistance may exist where artificial grounds are necessarily permitted in lieu of the preferable grounds to buried metallic water piping systems.

Mechanical protection and insulating guards should extend for a distance of not less than 8 feet above any ground, platform, or floor from which ground conductors are accessible to the public. (See also rule 246.)

Insulating mechanical protection is advisable for single arrester grounds, even when the connection is made to a water piping system, and has therefore a low resistance, since a single connection is liable to be accidentally broken.

Even where ground connections have a resistance not exceeding that specified in rule 96 and no guard is therefore provided (or as an additional protection to persons even where guards are used) artificial grounds may be arranged to minimize the potential gradient along the surface of the earth by use of radial connecting wires underneath the earth surface or by other suitable means.

A circuit ground conductor shall be guarded as required for current-carrying conductors of the circuit, unless the ground conductor is entirely outside buildings, has strength and current capacity not less than that of No. 6 copper wire, and the circuit is elsewhere grounded by other ground conductors; except that in stations substantial bare ground busses may be used.

(*d*) UNDERGROUND.—Wires used for ground conductors, if laid underground, shall, unless otherwise mechanically protected, be laid slack to prevent their being readily broken, and shall have joints carefully painted or otherwise protected against corrosion.

94. Nature of Ground Connection

The ground connection shall be permanent and effective and be made as indicated in (*a*), (*b*), (*c*), or (*d*) below; always as in (*a*), if (*a*) is available (except as per rule 97 *b*).

(*a*) PIPING SYSTEMS.—For circuits, equipment, and arresters at supply stations, connections shall be made to all available active continuous metallic underground water piping systems between which no appreciable difference of potential normally exists, and to one such system if appreciable differences of potential do exist between them. At other places connections shall be made to at least one such system, if available. Gas piping should not be used. (See rules 93 *a*, 95 *a*, and 95 *b*.)

"Available" in this rule means ordinarily within 500 feet for stations.

The protective grounding of electrical circuits and equipment to water pipe systems in accordance with these rules should always be permitted, since such grounding offers the most efficient protection to life and property and is not injurious to the piping systems.

(*b*) Alternate Methods.—Where underground metallic piping systems are not available, other methods which will secure the desired permanence and conductance may be permitted. In many cases metal well casings, local metal drain pipes, and similar buried metal structures of considerable extent will be available and may be used in lieu of extended buried water-piping systems.

In some cases ground connection may be made to the steel frame of a building containing the grounded circuits or equipment, to which frames of machines and other noncurrent-carrying surfaces should also then be connected. In such cases the building frame should be itself well grounded by effective connection to the ground. This may require artificial grounding for steel frame buildings supported on masonry or concrete (unreinforced) footings.

(*c*) Artificial Grounds.—When resort must be had to artificial grounds, their number should be determined by the following requirements:

(1) Not more than one such ground is required for lightning arresters, except where for large current capacity. At least two grounds are required for low voltage alternating-current distribution circuits at transformers or elsewhere.

(2) Where no part of the circuit or equipment protected can be reached by persons while they are standing on the ground or damp floors, or by persons while touching any metallic piping to which the ground wire is not effectively connected, a single artificial ground may be used even if its resistance exceeds that specified in rule 96. In such cases it is desirable to provide guards for the ground conductor in accordance with rule 93 *c* wherever it is otherwise accessible, or to provide insulating mats or platforms so located that persons can not readily touch the ground conductor without standing on such mats or platforms.

(*d*) Grounds to Railway Returns.—Protective ground connections should not be made to railway negative return circuits when other effective means of grounding are available, except ground connections from electric railway lightning arresters.

When ground connections are of necessity made to the grounded track return of electric railways, they shall be made in such a manner as not to afford a metallic connection (as indirectly through a grounded neutral with multiple grounds) between the railway return and other grounded conducting bodies (such as buried piping and cable sheaths).

This rule does not prohibit the making of drainage connections (which are not protective grounds) between piping systems and railway negative return circuits for the prevention of electrolysis.

Multiple protective ground connections from other circuits to railway returns should be avoided, and where multiple artificial grounds are made on such other circuits near such railway returns, they should be so arranged as to prevent the flow of any considerable current in and between such connections, thus reducing their effectiveness, or causing other damage.

95. Method.

(*a*) Ground connections to metallic piping systems should be made (except as permitted in *b*) on the street side of water meters, which might interrupt the continuity of the underground metallic-pipe systems, but connections may be made immediately inside building walls to secure accessibility for inspection and test. When water meters are located outside buildings or in concrete pits within buildings where piping connections are imbedded in concrete flooring, the ground connection may be made on the building side of the meters, if they are suitably shunted.

(*b*) When the making of a ground to a piping system outside meter or other device would involve a long run, connection for equipment or wire runways (but not for circuits) may be made to the water piping system at a point near the part to be protected, provided there are no insulating joints in the pipe to prevent a good ground. In such cases care should be taken to electrically connect all parts of the piping system liable to create a hazard (if they become alive) and to shunt the pipe system where necessary around meters, etc., in order to keep the connection with the underground piping system continuous.

Gas-piping systems within buildings should not be used for purposes of this rule, except that gas piping need not be insulated from otherwise well-grounded electrical fixtures and where the making of another ground connection for a fixture would involve a long run and the fixture is therefore, of course, not within reach of plumbing or plumbing fixtures, the gas piping may for small fixtures be utilized as the sole ground connection. Where so used the gas piping and water piping systems within the building shall be grounded at their points of entrance. (See rule 93 *a* and 94 *a*.)

(*c*) The ground connection to metallic piping systems should be made by sweating the ground wire into a lug attached to an approved clamp and firmly bolting the clamp to the pipe, after all rust and scale have been removed, or by soldering the ground connection into a brass plug which has been tightly screwed into a pipe fitting or, where the pipe is of sufficient thickness, screwed into a hole in the pipe itself, or connection may be made by other equivalent means. The point of connection should be as readily accessible as possible, and the position should be recorded.

With bell and spigot joint pipe it may be necessary to connect to several lengths where circuits or equipment of large current-carrying capacity are being grounded.

(*d*) Artificial grounds should be located where practicable below permanent moisture level, or failing this at least 6 feet deep.

Each ground should present not less than 2 square feet surface to exterior soil. Areas where ground water level is close to the surface should be used when available.

96. Ground Resistance

(*a*) LIMITS.—It is recommended that the combined resistance of the ground wires and connections of any grounded circuit, equipment, or lightning arrester should not exceed the values given below, if ground connections made according to rule 94 will sufficiently limit the resistance.

It will frequently be impracticable with artificial grounds to obtain resistances in dry or other high resistance soils as low as the values given below for ordinary soils. In such cases use two grounds as defined in rule 95 *d*, and no requirement will be made as to resistance. (See also rule 94 *c*–2.)

The current stated opposite the different resistances in the table is either the current capacity of a circuit from which leakage can occur to the grounded circuit, or the continuous current capacity to which the grounded equipment or arrester is limited by design or by automatic cutouts.

Where a secondary is exposed only through transformer windings, this current capacity will be that of the primary fuse of the transformer. Where the secondary is exposed by the conductors of conflicting or crossing high voltage circuits, the current capacities will be those of the automatic cutouts in such circuits.

Amperes	Water-pipe grounds	Artificial grounds, ordinary soils
	Ohms	*Ohms*
Less than 10	15	25
10 to 25	6	25
25 and above	3 or less	25

The product of the corresponding numbers in the first and second columns is never greater than 150—that is, the potential difference due to the stated current is never greater than 150 volts—where connections are made to water pipes.

Where more than one ground is made on the same circuit, equipment, or arrester, in the same vicinity, all such grounds are considered collectively in respect to meeting the requirements of this rule.

(*b*) CHECKING.—The resistance of station grounds should be checked when made. With artificial grounds this check may be made by measuring the voltage between the grounded point of the circuit, or the grounded frame of the equipment or the grounded point of the lightning arrester and an auxiliary metal reference rod or pipe driven into the ground, while a measured current is flowing through the ground connection and any exposed metal piping or other artificial ground in the vicinity, but not within 20 feet.

If the station ground is to water piping, the check may be made with current flowing through the water piping and some independent piping system or artificial ground in the vicinity, but not within 20 feet.

The auxiliary rod or pipe should be at least 10 feet from any artificial ground or piping systems through which the measured current is made to flow.

All ground connections shall be inspected periodically.

Ground connections on distribution circuits should, when installed, be tested for resistance unless multiple grounding to water piping systems is used.

97. Joint Use of Grounds and Ground Conductors for Different Systems

(*a*) Ground Conductors.—Ground conductors should be run separately to the ground (or to a sufficiently heavy grounding bus or system ground cable which is well connected to ground at more than one place) from equipment and circuits of each of the following classes:

1. Lightning arresters.
2. Secondaries connected to low voltage lighting or power circuits.
3. Secondaries of current and potential transformers and cases of instruments on these secondaries.
4. Frames of direct current railway equipment and of equipment operating in excess of 750 volts.
5. Frames of utilization equipment or wire runways other than covered by item 4.

(*b*) Grounds.—Lightning arrester ground connections shall not be made to the same artificial ground (driven pipes or buried plates) as circuits or equipment, but should be well spaced and, where practicable, at least 20 feet from other artificial grounds.

DISCUSSION OF SECTION 9[1]

90. Scope of the Rules

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 by the type of ground used.

OBJECT.—The object of protective grounds on electric circuits or equipment, as required in the rules of the code (by the method specified in this section), is to prevent passage of a harmful amount of electric current through the human body in case of contact by persons with the conductor or other part and other grounded surfaces. The amount of current which would be harmful depends largely on the voltage between any two surfaces between which a person can make connection with his body (for instance, between a conducting surface accessible to his hand and the surface on which his foot rests). It is desirable that any two conducting surfaces with which a person may simultaneously come in contact should be as nearly as practicable at the same potential. (See rule 94.)

MEDIUM.—Most conducting surfaces such as a person might touch among them plumbing fixtures, gas fixtures, machines, damp floors and walls, are in more or less good contact with earth, and it is ordinarily inconvenient and impracticable, and sometimes even dangerous, to effectively and reliably insulate them from earth. In order, therefore, that there may be as little potential difference as practicable between the surfaces above enumerated and noncurrent-carrying parts of electrical equipment or wire runways or the ground terminals of lightning arresters or the "grounded" wire of a circuit, it is usually the simplest plan to "ground" the electrical equipment or circuits to the earth itself, rather than individually to the various surfaces named. A suitable medium for securing good contact with earth should be utilized, by far the best medium being an underground metallic water piping system.

EFFECTIVENESS.—For circuits which are normally carrying current, a good connection with the earth is, of course, even more important than for frames of equipment, which will not normally be carrying current, since the passage of current through poor (high resistance) ground connections may cause heating or excessive rise of potential. This may temporarily destroy the effectiveness of the ground connection even though no other accident is caused at the time.

[1] A more detailed discussion of the problem of grounding (earthing) circuits is being prepared as a separate publication of the Bureau and will shortly be issued.

RESISTANCE.—It will be evident that a ground connection of low resistance is very desirable, but in some cases where the resistance of the soil is very high and where underground water mains are not present and accessible, it may be impracticable to secure as low a resistance as is desirable, and in such cases as good a ground should be obtained as is practicable under existing local conditions. (See rule 96.)

CURRENT-CARRYING GROUNDS.—If the protective ground connection normally carries current, it is part of a continuous 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 wire or the ground connection, but such a current could only result 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 ground wire by corrosion, the protection afforded by the artificial ground thus being lost.

MULTIPLE GROUNDS.—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, and the rules contain provisions to prevent appreciable interchange.

92. Where Ground Conductor Shall be Attached

(*a*) It is evident that the single ground connection permissible on two-wire direct-current circuits and the restricted number permissible on three-wire direct-current circuits do not provide quite the same assurance against loss of ground protection which is provided by the multiple grounds recommended for alternating-current distribution circuits. To more or less offset this relative lack of effectiveness of the direct-current circuit grounds there are several circumstances. Such circuits are usually underground or confined to private premises and are therefore relatively unexposed to higher voltages. Even where exposed their usually greater capacity than alternating-current distribution circuits makes the loss of the ground protection by breakage of the ground connection so unlikely as to warrant the restriction of the number of ground connections in order to eliminate any serious tendency toward electrolytic damage which might exist, if miscellaneous multiple grounds were permitted or required.

(*b*) Ground connections at all building services connected to any given secondary circuit are desirable, since they provide grounds which may be readily inspected and tested and because of their number afford good insurance against the entire loss of the ground connection. They also make the resistance to ground low enough to open automatic cutouts in the primaries supplying the secondary circuit before any considerable potential difference is established between the grounded circuit and piping systems with which a person might simultaneously come in contact.

Since lighting circuits with their frequent use of small portable appliances generally present more difficulty and expense in grounding non-current-carrying metal parts, and in guarding live parts (as on panel boards and the like) than do motor circuits, the provision of adequate protection is usually simpler if the lighting circuits are confined to a single phase (where a 2 or 3 phase system is used) and that phase is grounded, preferably at the neutral conductor if one is used. Where the maximum phase voltage is 220, guards and equipment grounding would then be often unnecessary for the devices connected to the lighting phase. (See rule 371.)

Where 2 or 3 phase systems are utilized for motors, the fixed character of such devices and their comparatively large size and infrequency, render the guarding of their 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 will need consideration, or its resistance may become too great and its current capacity too small.

93. Ground Conductor

(*a*) 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 such ground connections 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 existing in this case 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. This is along the line of giving the best insurance against interruption of ground connections and is further referred to in rule 95 *a* and *b*.

94. Nature of Ground Connection

(*a*) The increasing use of cemented joints in underground gas piping makes it inadvisable to place reliance on such systems as ground connections. There is also some objection to grounds on such systems from the possibility of arcing when removing sections of gas piping in which an explosive mixture of air and gas may exist.

(*b*) The metal frame of a building, where no buried metallic-piping systems are available, if well grounded by artificial grounds, may make a very effective ground, since the protection of persons does not require that the bond between the building frame and the earth at distant points be good, but requires only that the bond between the circuit or equipment in question and all conducting objects which he can touch at the same time, must be good.

These objects will include metal walls, damp floors, and heater 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 only from 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.

It is to be noted that for metal-clad buildings exposed to possible contact of circuits either within or without, the grounding of the metal covering is very advisable to protect passers-by from shock, and this is particularly the case when the metal covering is insulated from ground by a masonry or wood foundation.

96. Ground Resistance

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 which might cross the secondary protected by the ground in question, and not sufficient, therefore, to blow the primary fuses and so relieve the dangerous condition, would cause 1000 volts drop between the grounded conductor of the secondary and the earth. Clearly, under these conditions, such a ground connection would not eliminate the life hazard. In the case cited the energy 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 ground contact, and increase the resistance of the ground connection, thus raising the voltage still higher.

Water-piping ground connections fortunately provide a much lower resistance than 10 ohms, in fact, usually only a fraction of 1 ohm, and can safely dispose of any amount of heat likely to be developed by their resistances. Under all ordinary circumstances, therefore, water-piping grounds will insure against a dangerous rise of potential to ground on the grounded conductor or equipment. In case resort must be had to artificial grounds, the resistance may be reduced by using several such grounds in multiple, and this has the further advantage of insuring against the danger by breakage or drying out of a single artificial ground.

Where, however, a secondary circuit is exposed only through transformer windings, and not by reason of running under primaries or other circuits, the only fuse which need blow to protect against high potentials on the secondary is the transformer primary fuse. Even a single ground, of a resistance less than 25 ohms, would therefore allow a potential of only 250 volts on the secondary before blowing a 10-ampere primary fuse, and this might be a satisfactorily low resistance in such a case. Even here, however, the use of two grounds and two ground conductors would provide desirable insurance against loss of protection by the loss of either ground through corrosion or mechanical disturbance.

97. Joint Use of Grounds and Ground Conductors for Different Systems

It is usually bad practice to utilize a single ground wire, unless very substantial and of considerable current capacity, for several classes of equipment. The loss by breakage or accidental disconnection of the actual common ground connection or the use of a relatively poor connection will tend to make currents circulate between the different classes of equipment. Particularly harmful would be the passage of current from a lightning arrester of large capacity over an instrument secondary or a low voltage distribution secondary which serves devices or is handled by many persons. The installation of the different ground wires radially to a common ground, or, better yet, to different grounds, offers usually a greater degree of reliability and safety.

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

CONTENTS

GENERAL PROTECTIVE REQUIREMENTS

Sec. 10. PROTECTIVE ARRANGEMENTS OF STATIONS AND SUBSTATIONS

100. Scope of the Rules

The following rules apply to the electrical supply equipment of indoor and outdoor stations and substations. They also apply to similar equipment, including generators, motors, storage batteries, transformers, and lightning arresters when installed in factories, mercantile establishments, vehicles, or elsewhere, provided the equipment is in separate rooms or inclosures, under control of properly qualified persons, if the interiors of such rooms or inclosures are accessible only to such persons.

101. Application of the Rules and Exemptions

(*a*) The rules are intended to apply to all such installations, except as modified or waived by the proper administrative authority or its authorized agents and are intended to be so modified or waived in particular cases whenever any rules are shown to involve expense not justified by the protection secured, or for any other reason to be impracticable; or whenever it is shown that equivalent or safer construction can be more readily provided in other ways.

(*b*) The intent of the rules will be realized (1) by applying the rules in full to all new installations, reconstructions, and extensions, except where any rule is shown to be impracticable for special reasons or where the advantage of uniformity with existing construction is greater than the advantage of construction in compliance with the rules; (2) by placing guards on existing installations or otherwise bringing them into compliance with the rules, except where the expense involved is not justifiable.

The time allowed for bringing existing installations into compliance with the rules will be determined by the proper administrative authority.

(*c*) It will sometimes be necessary to modify or waive certain of the rules in cases of temporary installations or installations which are shortly to be dismantled or reconstructed.

(*d*) In cases of emergency or pending decision of the administrator, the person responsible for the installation may decide as to modifications or waiver of any rule, subject to review by proper authority.

102. General Requirements

All rooms or spaces in which electrical supply equipment is installed shall comply with the following requirements:

(*a*) They shall be used neither for the storage of material nor for manufacturing processes causing hazard to electrical operators, except those materials or processes attendant upon the production or distribution of a supply of electrical energy.

(*b*) They shall be free from flyings and inflammable gas (excepting battery rooms, see section 13); indoor stations should be dry and well ventilated.

(*c*) In outdoor stations or stations in wet tunnels or subways all live parts of equipment should be inclosed in weather-proof cases, unless the equipment is suitably designed to withstand the prevailing atmospheric conditions and the live parts are suitably guarded against contact, or isolated by elevation.

Ungrounded conductors not in conduit should be on suitable insulators, properly guarded or isolated by elevation.

103. Illumination

(*a*) Rooms and spaces shall have good artificial illumination. Arrangement of permanent fixtures and plug receptacles shall be such that portable cords need not be brought into dangerous proximity to live electrical apparatus. All lamps shall be arranged to be controlled, replaced, or trimmed from readily accessible places.

(*b*) A separate emergency source of illumination, from an independent generator, storage battery, gas main, lanterns (the latter two should never be used in battery rooms), or other suitable source, shall be provided in every station where an attendant is located.

104. Inclosing Walls and Ceilings

(*a*) Rooms and spaces shall be so arranged with fences, screens, partitions, or walls, as to prevent entrance of unauthorized persons or interference by them with equipment inside, and entrances not under observation of an authorized attendant shall be kept locked. Signs prohibiting entrance to unauthorized persons shall be displayed at entrances.

(*b*) Above all equipment substantial roofs or ceilings shall be provided, except above equipment placed outdoors, where such portions of the equipment as would be injured by rains or by flying or falling objects are suitably inclosed or guarded to prevent such damage.

105. Floors, Floor Openings, Passageways, Stairs

(*a*) Floors shall have even surfaces and afford secure footing. Projecting nails, loose boards, uneven or greasy wood floors, and smooth iron floors should be avoided.

(*b*) Passageways (including stairways) and working spaces shall be unobstructed, and (except such as are used solely for infrequent inspection, construction and repair) shall, where possible, provide at least 6.5 feet headroom. (See rule 114.)

(*c*) All floor openings over 2 feet deep, and all stairways or raised platforms over 4 feet high shall be provided with suitable handrails.

Except for loading platforms, such rails are recommended where height exceeds 2 feet, especially where they are adjacent to live or moving parts, or the working space on the platform is restricted.

(*d*) All floor openings over 6 feet deep, and the edges of all raised platforms over 6 feet high, shall, where possible, be provided with suitable toe boards.

(*e*) Toe boards shall, where possible, be arranged at back of stairway treads where over exposed live or moving parts or over working spaces, passageways, or other stairways.

106. Exits

(*a*) Each room or space and each working space about equipment shall have suitable means of exit which shall be kept clear of all obstructions.

(*b*) If the plan of the room or space and the character and arrangement of equipment are such that an accident would be liable to prevent an employee from getting out of the room through a single exit, as in the case of long narrow rooms, platforms or passageways, a second exit shall, if practicable, be provided.

107. Fire Fighting Appliances

Each room or space where an operator is in attendance shall be provided with adequate approved fire-extinguishing appliances conveniently located and conspicuously marked. Any such appliances which have not been approved by Underwriters' Laboratories for use on live parts should be plainly and conspicuously marked with a warning to that effect whenever placed in rooms containing exposed live parts over 300 volts to ground.

Sec. 11. PROTECTIVE ARRANGEMENTS OF EQUIPMENT

110. General Requirement

All electrical supply equipment shall be of such construction and so installed and maintained, as to reduce the life hazard as far as practicable.

111. Inspections

Electrical supply equipment shall comply with these safety rules when placed in service, and shall thereafter be periodically cleaned and inspected. Defective equipment shall be put in good order or permanently disconnected. Defective wiring, when hazardous, shall be repaired or removed.

112. Infrequently Used Equipment

Infrequently used equipment or wiring maintained for future service should be periodically inspected to determine its fitness for service.

113. Protective Grounding

(*a*) GROUNDING METHOD.—All lightning arrester grounding, and all grounding of circuits, equipment, or wire runways, which is intended to be a permanent and effective protective measure, shall be made in accordance with the methods specified in Section 9, Method for Protective Grounding.

(*b*) GROUNDING NONCURRENT-CARRYING METAL PARTS.—All electrical supply equipment, if operating at over 150 volts to ground, or if in hazardous locations, shall have their exposed noncurrent-carrying metal parts, such as frames of generators, motors, and switchboards, and cases of transformers and oil switches, permanently grounded. (See rules 124 *b* and *c*, and 168.)

When for purposes of voltage regulation, generators or converters supplying circuits not exceeding 150 volts to ground, are operated at not more than 180 volts they are considered as not exceeding 150 volts to ground.

Hazardous locations include those where dampness, acid fumes, explosives, inflammable gas, or flyings normally exist.

(*c*) EXCEPTIONS.—Exposed noncurrent-carrying metal parts of electrical supply equipment operating on grounded direct-current circuits or on series direct-current circuits may be left ungrounded where no inflammable gas is present, provided that suitable insulating floors, platforms, or mats are used, so that no person can inadvertently come in contact with such ungrounded parts while he is standing upon any grounded surface (including floors not of insulating material); and also that suitable permanent insulating barrier guards are used so that the person can not, while touching the ungrounded parts, at the same time inadvertently touch other machine frames or metallic fixtures not bonded to the parts in question. This rule, where providing for barrier guards, does not apply to the motor frames of direct-connected, motor-driven, high-tension, series generator sets in existing installations, where for operating reasons the generators must have their frames insulated from ground, and the motor frames are grounded, if it is impracticable to provide insulating barrier guards in the space available. (See rule 124.)

(*d*) Where exposed noncurrent-carrying metal parts are not grounded they shall be suitably insulated from the ground, and from neighboring grounded surfaces.

114. Working Space about Electrical Equipment

(*a*) Adequate working space with secure footing shall be maintained about all electrical supply equipment which requires adjustment or examination during operation. (See rule 105 *b*.)

Working spaces about exposed live parts over 300 volts to ground shall be made inaccessible to other than authorized attendants by the use of suitable barriers when necessary.

(*b*) The spaces shall be so arranged as to give the authorized attendants ready access to all parts requiring attention, and shall, where practicable (except where used only for infrequent construction, inspection, and repair), provide the following minimum working spaces:

(1) If there are exposed live parts from 300 volts up to 750 volts on one side, the minimum width shall be 2.5 feet; above 750 volts, not less than 3 feet.

(2) If there are exposed live parts from 300 volts up to 750 volts on both sides, the minimum width shall be 3 feet; above 750 volts, not less than 5 feet.

115. Guarding Live Parts

(*a*) Protection shall be provided for persons near otherwise exposed ungrounded current-carrying parts of electrical supply equipment (such as bus bars and other conductors or the terminals of generators and motors), operating at over 300 volts to ground and not effectively isolated by elevation (except where these parts are away from passageways and working spaces, used for frequent construction, inspection, and repair), as given below.

(*b*) Where the working space about electrical equipment is less than that specified in rule 114 *b*, 1 and 2, suitable inclosures or barriers shall be provided to prevent inadvertent contact with live parts. If such inclosures must be opened or barriers removed while the parts they guard are alive, all surrounding floors shall be provided with suitable insulating platforms or mats, so placed that the operator can not readily touch the live parts without standing on the mat or platform.

Inclosures may consist of suitable casings or suitable insulating coverings. The insulating covering of conductors should be depended upon only when it is impracticable to install more suitable guards and then only when very substantial, thoroughly dry, and containing no noninsulating flame-proofing compound or oil-soaked rubber.

Barriers may consist of horizontal or vertical strips placed in front of current-carrying parts, or of closely spaced partitions between such parts, extending beyond the exposed sides of the current-carrying parts.

Where covers, casings, or barriers must at any time be removed while the parts which they guard are alive, they should be of insulating material, or so arranged that they can not readily be brought in contact with the live parts.

Mats may be of wood, held together by wood pins, or of cork matting, linoleum, or rubber. The material and construction should be suitable for the voltage concerned and for the prevailing conditions. If subject to moisture or to accumulations of conducting dust, flyings, or chips, mats should provide surfaces minimizing the hazards from these sources.

(*c*) Where the specified working spaces are provided and the current-carrying parts are not guarded by inclosures or barriers the insulating platforms or mats shall always be provided.

(*d*) Where the current-carrying parts operate at over 7500 volts the inclosing or barrier guards shall always be provided even where insulating mats are also provided.

Inclosing or barrier guards not of grounded metal should be of substantial material and spaced from the current-carrying parts not less than three times the needle-point sparking distance, at the voltage concerned, of the intervening air, oil, or other dielectric. This rule does not apply to direct-connected, motor-driven, high-tension, series generators, which for operating reasons must have their frames insulated from ground.

(*e*) Bare parts at different potentials shall be effectively separated. Such parts in circuits of large capacity or operating at above 7500 volts shall, unless provided with inclosures or other guards specified in (*b*) above, be provided with suitable barriers, if practicable, so that they will not be short-circuited by tools or other conducting objects.

116. Isolating Live Parts by Elevation (for Switchboards see rule 176 *c*).

Current-carrying parts need not be guarded if they are maintained at the following distances above the floors which may be occupied by persons:

Voltage of conductors:	Elevation in feet.
300 to 750	7.0
750 to 2 500	7.5
2 500 to 7 500	8.0
7 500 to 30 000	9.0
30 000 to 70 000	10.0
70 000 to 100 000	12.0
Over 100 000	14.0

117. Identification

(*a*) Electrical supply equipment shall be suitably identified when necessary for safety. The identification may be by position, color, number, name plate, label, design, or other means.

(*b*) The voltage and intended use shall be shown when important.

ROTATING EQUIPMENT, STORAGE BATTERIES, AND TRANSFORMERS

Sec. 12. ROTATING EQUIPMENT

(This includes generators, motors, motor-generators, and converters.)

120. Speed-Control and Stopping Devices

(*a*) Prime movers driving generating equipment shall be provided with automatic speed-limiting devices (in addition to their governors, if necessary, as with some types of steam turbines) where harmful overspeed can otherwise occur.

(*b*) Separately excited direct-current motors, series motors, and motor-generators and converters, where it is possible for them to be driven at an excessive speed from the direct current end by a reversal of current or decrease of load, shall be provided with speed-limiting devices, unless the load and the mechanical connections thereto are of such a character as to safely limit the speed.

(*c*) Where the speed control of direct-current motors is accomplished by varying the field resistance, and the nature of the load and the range of the field rheostat are such as to make a dangerous speed attainable and no speed-limit devices are used, the field rheostats shall be arranged with no-voltage releases or other devices so that the motor can not be started or continued in operation under dangerously weakened field, except where a hazard to service or apparatus might result from operation of such a device.

(*d*) Stopping devices, such as switches or valves which can be operated from locations convenient to machine operators, shall be provided for prime movers or motors driving generating equipment.

(*e*) Where speed limiting or stopping devices are electrically operated the control circuits by which such devices are actuated shall be in conduit or otherwise suitably protected from mechanical injury.

121. Protecting Shaft Ends, Pulleys, Belts, and Other Moving Parts

Pulleys, belts, and shaft ends projecting through bearings, revolving armatures, revolving fields, and other moving parts shall either be entirely inclosed in suitable casings or otherwise adequately guarded by rails or barriers, where persons would be liable to be injured by those parts.

122. Guards for Live Parts

(*a*) Suitable insulating mats or platforms of substantial construction and providing good footing shall be so placed on floors and, if necessary, on frames of machines having exposed live parts above 300 volts to ground, that operators can not readily touch such parts unless standing on the mat or platform.

(*b*) For parts above 750 volts, suitable inclosing or barrier guards shall, if practicable, be provided (in addition to mats or platforms), and so arranged that the operator can not inadvertently touch at the same time these live parts and any neighboring grounded parts.

(*c*) Where necessary, steps and handrails shall be installed on or about large machines to afford ready access to live parts which must be examined or adjusted during operation.

(*d*) Where switches are installed on the frames of generating equipment for the purpose of reducing inductive voltage in generator and converter field coils they shall be suitably constructed or guarded to prevent passers-by from inadvertently coming in contact with the live parts, to protect persons handling them, and to prevent their being accidentally opened or closed.

(*e*) Suitable shields or barriers shall be provided where necessary to prevent arcs from large commutators or circuit breakers from injuring persons in the vicinity as in the case of narrow switchboard galleries or similar working spaces located immediately above or beside such equipment.

123. Hazardous Locations

(*a*) In locations where explosives, inflammable gas or inflammable flyings normally exist in dangerous quantities all parts at which sparking or arcing are liable to occur shall be so inclosed as to reduce the hazard as far as practicable.

This inclosure shall be by one of the following methods:

(1) By placing in separate compartments or rooms.

(2) By using casings of the inclosed type when inflammable dust or flyings are present.

(3) By using explosion-proof casings when inflammable gases exist in dangerous quantities.

(*b*) All casings shall be nonabsorptive and noncombustible, and when of metal shall be permanently grounded if within reach of grounded surfaces.

124. Grounding Noncurrent-Carrying Parts

(*a*) All exposed noncurrent-carrying metal parts of rotating electrical supply equipment shall be permanently grounded in accordance with the requirements for grounding provided in rule 113.

(*b*) Where machine frames such as those of series arc light generators or direct-current railway generators are necessarily ungrounded, suitable insulating floors, mats, or platforms providing good footing shall be so placed that no person can readily touch the machine frame unless standing on such floor, mat, or platform.

(*c*) Where two or more machines, either of which operates at over 150 volts to ground, are mechanically coupled together and the operator can touch the frames of more than one at a time, the frames of all such shall be permanently grounded or bonded together electrically. This rule may be waived with high-voltage series generator sets in existing installations where for operating reasons the generators must have their frames insulated from the ground and the motor frame is grounded, and where it is impracticable to place insulating barriers between the grounded and ungrounded frames.

(*d*) Exciters and auxiliary circuits electrically connected to generators or other machines over 750 volts to ground (with frames ungrounded) shall be installed, protected, and identified as machines and circuits of the same voltage as that of the machine for which they are auxiliaries. (See also rule 141.)

125. Deteriorating Agencies

(*a*) Suitable guards or inclosures shall be provided to protect exposed current-carrying parts, insulation of leads, balance coils, or other electrical devices belonging to motors and generating equipment where installed directly under equipment or in other locations where dripping oil, excessive moisture, steam, vapors, or similar injurious agents exist.

(*b*) The metal frames and other exposed noncurrent-carrying metal parts of equipment in these locations shall be permanently grounded.

Sec. 13. STORAGE BATTERIES

The following rules (except 133) apply only to storage batteries exceeding 50 kilowatt hours capacity at the eight-hour rate of discharge.

130. Isolation

Storage batteries shall be made inaccessible to other than properly qualified persons by being placed in a separate room or inclosure.

131. Ventilation

Rooms or inclosures containing storage batteries shall be so ventilated as to remove acid spray and prevent dangerous accumulation of inflammable gas.

Communication of drafts to other rooms should be prevented.

132. Suitable Supports and Floors

The cells shall be supported by suitable insulators, except small cells of insulating material. Suitable drainage or other means shall be provided beneath cells to prevent the accumulation of electrolyte in case of leakage or spraying.

Acid-resistive floors, such as vitrified brick set in pitch, are recommended where large batteries are installed.

133. Guarding Live Parts in Battery Rooms

(*a*) The arrangement of cells and connections shall be such that no two current-carrying parts between which a voltage exceeding 150 exists, shall be closer than 3 feet, if the parts are so exposed that persons are liable to make accidental contact with both at the same time.

(*b*) No conductor above 150 volts to ground shall be placed in any passageway, unless guarded or isolated by elevation.

134. Illumination

Storage-battery rooms should be lighted, if practicable, from outside lamps. If lamps are inside, only incandescent electric lamps in keyless porcelain or composition sockets, controlled from points not exposed to battery vapor, shall be used.

135. Acid-Resistive Coverings

Conductors in battery rooms, if of such material or so located as to be liable to corrosion, shall have suitable protective coverings or coatings, unless the ventilation is such as to render this unnecessary.

Sec. 14. TRANSFORMERS, REACTANCES, INDUCTION REGULATORS, BALANCE COILS, AND SIMILAR EQUIPMENT

140. Current Transformer Secondary Circuits

(*a*) Secondary circuits of current transformers, including constant-current and instrument transformers (except those supplying relays only, or those having their primary circuits always disconnected before the secondary circuits are worked on), shall be provided with means for short-circuiting them which can be readily connected while the primary is energized and which are so arranged as to permit the removal of any instrument or other device from such circuits without opening the circuits.

(*b*) Where primaries are above 7500 volts, secondary circuits, unless otherwise adequately protected from injury or contact of persons, shall be in permanently grounded conduit.

141. Grounding Low-Voltage Circuits of Instrument Transformers

The low-voltage circuits of all instrument transformers shall be permanently grounded unless the circuits are installed, guarded, and plainly identified as required for the high-voltage circuits of the transformers.

This will sometimes require marking to distinguish such a low-voltage cricuit from others with which it is associated, but which are protected by ground connections.

142. Grounding Transformer Cases

The metal case or exposed frame of each transformer, reactance, and similar equipment, which is located where dampness or inflammable gas normally exists, or which is connected to a circuit operating at over 150 volts to ground, shall be permanently grounded.

Exception is permissible in locations free from inflammable gas, where the entire transformer is isolated or guarded as required for the highest voltage circuit connected with the transformer, and is plainly and conspicuously identified as of that voltage.

143. Transformers

Transformers shall be installed according to one of the following methods:

On poles or (when permitted by local authority) on walls of buildings, in which case they shall comply with overhead line rules. (See rules 247 and 253.)

In rooms in which other equipment is installed, in which case the construction, grounding and guarding for live parts shall comply with the rules covering station construction or utilization equipment, as they may apply in each case.

In transformer vaults or rooms which shall be made inaccessible to unauthorized persons.

Where the amount of oil in transformer casings is considerable and the transformers are located in buildings used for other than station purposes, they should be placed in suitable transformer vaults. (See rule 308.)

WIRING AND PROTECTION AND CONTROL EQUIPMENT

Sec. 15. CONDUCTORS

150. Electrical Protection

(*a*) Conductors shall be suitable for the location, use, and voltage. Conductors should be protected against excessive heating by the design of the system or by automatic cut-outs, except grounded conductors, field excitation circuits, circuits supplying interconnected 3-wire systems of underground distribution, and other circuits the opening of which may cause special hazard to life through interruption of service.

Such automatic cut-outs may be set so as to interrupt the circuits only on excessive short circuits, if constant attendance is provided and protection is thus also afforded by manual operation.

(*b*) Conductors normally grounded for the protection of persons shall be arranged without automatic cut-outs interrupting their continuity between the source of energy and the point at which the ground wire is attached, unless the operation of such a cut-out automatically results in the immediate disconnection of the grounded circuit from all sources of electrical energy.

(*c*) Conductors shall be provided with one or more suitable switches to effectively disconnect them from all sources of electrical energy.

151. Mechanical and Thermal Protection

(*a*) Where exposed to mechanical injury suitable casing, armor, or other means shall be employed to prevent injury or disturbance to conductors, their insulation, or supports.

(*b*) Where conductors with insulating coverings are closely grouped (as sometimes on the rear of switchboards or in cableways) they shall have a substantial flame-proof outer covering.

(*c*) Large uninsulated conductors liable to be torn from their supports by the stresses to which they are subjected (as by the magnetic fields produced) shall be so supported that they can not come in contact with the surfaces along which they are run or with other conductors.

152. Isolation by Elevation

All conductors over 750 volts, and ungrounded bare conductors over 300 volts to ground shall be isolated by elevation (as required by rule 116), unless guarded in accordance with rule 153, so that no person can inadvertently come in contact with them; provided that busses and bus structures and line connections thereto, installed in accordance with rules 114 and 169 *d*, in suitable locations specially arranged for such purposes, shall not be required to be so isolated.

153. Guarding Conductors

(*a*) Use of Inclosing Casings.—Where insulated conductors are inclosed, suitable permanently grounded metal conduit or grounded metal sheathing shall be used; or in lieu thereof other ducts, runways, or compartments of tile, bitumenized fiber, concrete, or other suitable fire-resistive materials may be used, if containing no exposed combustible material. In damp places, conduit, ducts, or runways shall be made waterproof and be provided with suitable means for draining off condensation, unless the conductors contained are lead-sheathed cables.

(*b*) Conductors Above 750 Volts in Conduit or Sheathing.—Conductors operating at over 750 volts (unless separately supported and effectively isolated by elevation or by inclosing in suitable compartments or screens, as in paragraph *d*) shall be suitable metal-sheathed cable, run in metal conduits or suitable fire-resistive ducts or compartments, with the metal sheathing permanently grounded. Other covering may be used in suitable grounded metal conduit or insulating duct, when installed in dry locations. The conduit or duct shall provide a smooth runway, with smooth outlets. Metal conduit, if used, shall be made electrically and mechanically continuous with the metal casings of all conduit fittings.

(*c*) Metal-Sheathed Cable Outlets Above 750 Volts.—The insulation of the several conductors of multiple conductor cable, where leaving the metal sheath at outlets, shall be thoroughly protected from mechanical injury, moisture and electrical strains by means of a pot head or equivalent method.

(*d*) Open Conductors Above 750 Volts.—When any open insulated conductor above 750 volts, or any open bare conductor above 300 volts to ground, is necessarily brought closer to the floor line than the clearances required for isolation by elevation, they shall be guarded by permanent screens, by inclosing partitions, or by suitable barrier guards.

(*e*) Where barrier rails only are used, the surrounding floors shall be provided with suitable insulating platforms, mats, or covers. (See rule 115 *b*.)

154. Guarding in Hazardous Locations

(*a*) Conductors in locations where inflammable gas normally exists shall be in metal conduit or metal-sheathed cable. All fittings and outlets of such conduit and cable shall be electrically and mechanically continuous with the conduit or metal sheath, and the conduit shall be sealed to prevent entrance of gases.

(*b*) Conductors in damp locations, if neither in conduit nor in waterproof metal sheaths in other suitable ducts, shall be effectively isolated and supported on a suitable type of insulator.

155. Pendants and Portables

(*a*) Pendant conductors shall not be installed where they can readily be moved so as to bring them in contact with live parts of electrical supply equipment.

(*b*) Portable conductors shall be attached to fixed wiring only through separable attachment plugs which will disconnect all poles by one operation. (See sec. 37.)

156. Temporary Wiring

Temporary wiring which is not in compliance with these rules may be used when it is constantly under competent supervision or protected by suitable barrier guards and warning signs while it or neighboring wiring is alive and accessible to any person.

157. Taping Ends and Joints

Ends and joints of insulated conductors, unless otherwise adequately guarded, shall have equal insulating covering with other portions of the conductor.

Sec. 16. FUSES AND OTHER CUT-OUTS; SWITCHES AND CONTROLLERS

160. Accessible and Indicating

All switches, automatic cut-outs, starting rheostats, and other control devices shall be readily accessible to authorized persons. They shall be so arranged or marked as to identify the equipment controlled by them, and (except fuses) shall indicate whether they are open or closed. They shall be so installed as to minimize the danger of accidental operation, and where practicable so that gravity can not close them; such switches as close by gravity shall be provided with a proper latch or stop block to prevent accidental closing. Where practicable, the blades of knife switches should be dead when the switches are open.

161. Hazardous Locations

In locations where explosives, inflammable gas or inflammable flyings normally exist in dangerous quantities, all parts at which sparking or arcing are liable to occur shall, if practicable, be so inclosed as to prevent hazard. (See rule 123.)

162. Where Switches are Required

(*a*) Suitable switches or cut-outs which may be manually operated shall be inserted in all leads (except a grounded conductor) to generators, motors, transformers (except instrument transformers) and all outgoing supply circuits.

(*b*) In most cases the switch called for should be capable of opening the circuit under overloads. In some cases as between generators and transformer banks used with them, disconnectors only would be required.

(*c*) Where two or more pieces of electrical supply equipment or supply lines are operated as a single unit no switch is necessarily required between them.

(*d*) Switches shall not be required in underground manholes or in transformer vaults except as may be deemed necessary by the utility to meet operating requirements.

163. Switches or Other Grounding Devices

It is recommended that switches or other suitable means be provided, where practicable, to facilitate short-circuiting and grounding equipment or lines for which the operating rules require grounding to protect workmen. (See secs. 45–46.)

164. Character of Switches and Disconnectors

(*a*) Capacity.—Switches used otherwise than as disconnectors shall be of suitable voltage and ampere rating for the circuit on which they are installed, and be marked with the current which they can safely interrupt.

Disconnectors shall be of suitable voltage and ampere rating for the circuit on which they are installed, and shall be marked with warning against opening when carrying load. Where a group of disconnectors is contained in one room or compartment a single conspicuous sign may be sufficient.

(*b*) Locking.—Remotely controlled switches, oil switches and disconnectors shall be so arranged that they can be secured or blocked in the open position and plainly tagged to prevent careless closing while work is being done on equipment controlled by them, unless the switches are so constructed or installed as to prevent accidental closing or all live or moving parts of the equipment they control are so guarded as to render blocking and tagging unnecessary.

For switches and disconnectors the accidental opening of which may cause hazard, similar arrangements are desirable for retaining them in closed position.

Locking is recommended rather than blocking wherever parts of equipment are remote from the point of control.

Locking or securing doors of compartments is one means of securing switches in the open position to prevent careless closing while work is being done on the equipment controlled. Blocking the jaws of knife switches is also a common method.

(*c*) Air Break.—Unless a switch operating on a circuit above 750 volts makes an air break it is recommended that there shall be installed between it and the source of energy supply a suitable air or oil break disconnector or equivalent device having an air or oil gap suitable for the operating voltage of the circuit (See rule 437.)

(*d*) Alignment.—Knife switches shall maintain such alignment under service conditions that they can be closed with a single unhesitating motion.

165. Where Automatic Cut-outs are Required

(*a*) All circuit leads to motors, transformers, or station auxiliaries shall be protected by suitable automatic cut-outs, except as noted in rule 150.

(*b*) Where two or more pieces of electrical supply equipment or supply lines are operated as a single unit no automatic cut-out is necessarily required between them.

166. Disconnection of Fusible Cut-outs Before Handling

Fusible cut-outs in circuits operating at over 150 volts to ground shall be arranged in one of the following ways:

(*a*) The ungrounded current-carrying parts can not be touched by persons re-fusing the cut-outs until the fuses have been disconnected from all sources of electrical energy.

(*b*) The cut-out can be disconnected by a suitable switch in series.

(*c*) The fuse can be conveniently handled by means of insulating handles or portable appliances provided for the purpose.

Fusible cut-outs below 150 volts to ground and less than 60 amperes capacity are exempted from the provisions of this rule.

167. Arcing or Suddenly Moving Parts

(*a*) Fuses and circuit breakers shall, as far as possible, be so located and shielded that persons will not be burned by their operation.

(*b*) Handles or levers of circuit breakers and similar parts which may move suddenly, in such a way that persons in the vicinity are liable to be injured by being struck by them, shall be guarded or isolated, where practicable.

168. Grounding Noncurrent-Carrying Metal Parts

Exposed noncurrent-carrying metal parts of switch and fuse cases, levers, and other similar parts to which leakage is liable to occur from live parts, and thereby create a hazard, shall be permanently grounded according to the provisions of rule 113.

Minor parts, such as ferrules of knife switches, which are not liable to become alive, are excluded.

169. Guarding Live Parts of Switches and Automatic Cut-outs Not Installed On Switchboards

(*a*) Above 750 Volts.—All switches interrupting circuits over 750 volts shall be operated by means of remote control mechanisms or be provided with suitable casings protecting the operator from danger of contact with current-carrying parts, except as provided in (*d*) below, for switches requiring only infrequent attention and located in inclosures from which even the operator is normally excluded. The control devices for switches shall indicate whether switches are open or closed. Lever-operated, circuit-breaker-type switches should be equipped with indicating devices to show, other than by the position of the handles, whether they are open or closed. All automatic cut-outs not suitably isolated by elevation shall be of an incased type or be provided with suitable inclosures for all current-carrying parts.

Large-capacity, high-voltage oil switches should, where practicable, be placed away from the operator and operated by remote (or lever) control, since the blowing up of the oil containers may cause serious injuries to persons in the vicinity.

For the purpose of this rule voltages in excess of 750 will be included as below 750 where the excess is for purposes of regulation only.

(*b*) Below 750 Volts.—All switches interrupting circuits under 750 volts shall be operated by means of remote-control mechanisms or be incased during ordinary operation or be provided with insulating handles and insulating guard disks or shields, so arranged as to make it unlikely that the hand will come in contact with live parts.

Switches below 300 volts to ground may be exempted from the above requirement.

(*c*) Platforms or Mats.—Where live parts of switches or automatic cut-outs operating at over 300 volts to ground are not remotely controlled, or provided with inclosing guards effective during ordinary operation or adjustment, or isolated by elevation, suitable insulating floors, mats, or platforms shall be provided on which the operator must stand while operating the switches or adjusting the automatic cut-outs. (See rule 115 *b*.)

(*d*) Working Spaces About Occasionally Exposed Live Parts.—Where switches, disconnectors, and fuses above 750 volts are ordinarily guarded by covers or inclosed in separate rooms, but must occasionally be operated without such protection, either by removal of the covers or by entrance into the rooms, adequate working space shall be provided about the live parts (unless effectively isolated by elevation as required by rule 116), so that the operator will not be required to bring any part of his body within the following horizontal distances:

Voltage of parts:	Distances in feet.
750 to 7 500	1
7 500 to 30 000	2
30 000 to 50 000	3
50 000 to 70 000	4
70 000 to 100 000	5
Above 100 000	6

(*e*) The distances given above are slightly greater than those required to be maintained by operators near parts of the corresponding voltages (see rules 441–442). This is for the purpose of providing against inadvertent movements of operators and to insure that operators of unusual height or size may be protected by the rule.

(*f*) Below 7500 volts the distance above specified may be reduced if the operator uses suitable operating devices.

Sec. 17. SWITCHBOARDS

170. Accessibility and Convenient Attendance

Switchboards shall have all switches so arranged that the points of control are readily accessible to the operator. Instruments, relays, and other devices requiring reading or adjustment shall be so placed that work can be readily performed from the working space. (See rules 169 *d* and 176 *c* and *d*.)

171. Location and Illumination

(*a*) Switchboards shall, where practicable, be so placed that the operator will not be endangered by any live or moving parts of machinery or equipment located near the board.

(*b*) Sufficient illumination shall be provided both for the front and rear of the switchboard so that the switchboard may be readily operated and instruments conveniently read.

172. Necessary Equipment

Switchboards which control outgoing supply circuits shall (except in substations without regular attendance) be equipped with such instruments as are necessary to show operating conditions.

173. Arrangement and Identification

Connections, wiring, and equipment of switchboards and panel boards shall be arranged in an orderly manner and all switches and cut-outs shall be plainly marked, labeled, or arranged so as to afford ready means for identifying circuits or equipment supplied through them.

174. Spacings and Barriers Against Short Circuit

(*a*) Switchboards shall have the number of bare parts at different potentials on any panel reduced to a minimum, and these parts shall be effectively separated. Protection or separation of such parts by suitable barriers is recommended where the voltage exceeds 750.

It is recommended that such parts, including bus bars, should be so located, or provided with such insulating coverings or barriers, that parts at different potentials will not be readily short-circuited by tools or other conducting objects,

(*b*) Fuses should be so located as to minimize the danger, in removing or replacing them, of short-circuiting parts at different potentials by the fuses or by the hands of the operator.

175. Grounding

Switchboard frames shall be permanently grounded under the conditions and with the exceptions noted in rule 113.

Where protective grounds are occasionally required on circuits for the protection of workmen, a permanent ground connection shall be provided, and also suitable means for effectively and readily connecting the parts being grounded to the ground connection. (See rule 163.)

176. Guarding Live Parts

(*a*) Inclosure.—All switchboards operating at over 300 volts to ground and located near passageways shall be guarded from these by suitable inclosures or barriers and shall (unless under constant attendance during operation) be made inaccessible to other than authorized persons.

(*b*) Mats.—For the protection of the operator, where parts over 300 volts to ground are not otherwise guarded or isolated by elevation, suitable insulating floors, mats, or platforms providing good footing shall be so placed that the operator can not readily touch the live parts, unless standing on such floors, mats, or platforms.

(*c*) PARTS OVER 750 VOLTS ON FACE OF BOARD.—No switchboard shall have exposed on its face within 6 feet from floor line any current-carrying part over 750 volts, except as noted in paragraph (*e*) below, and excepting direct-current railway boards up to 1,500 volts, which, where above the nominal 750 volts, shall be so constructed that the operator can not inadvertently come in contact with parts having a hazardous difference of potential.

Dead face panels and remote control are recommended as means for accomplishing this result where isolation by elevation is impracticable or undesirable.

(*d*) EXPOSED LIVE PARTS ON FACE OR BACK.—When working space adjacent to live parts can not be provided in accordance with rule 114 *a* and *b*, suitable guards shall be arranged to protect the operator from accidental contact with parts over 750 volts.

Suitable insulating guard rails, sufficiently spaced from the face or back of the board, or suitable guards perpendicular to the face or the back of the board, and extending out beyond the live parts, are recommended, where practicable.

(*e*) PLUG-TYPE SWITCHBOARDS.—Plug-type switchboards should, except while connections are being changed, have no current-carrying part exposed on face of boards and, if practicable, they and their plug connectors shall be so arranged where the operating voltage exceeds 150 as to have all current-carrying parts guarded so long as they are alive, even while connections are being changed.

(*f*) INSTRUMENTS.—Metal cases of instruments (unless isolated by elevation) operating at over 750 volts should be grounded or inclosed in suitable covers of insulating material or of grounded metal.

(*g*) EXPOSED PARTS OVER 7500 VOLTS.—No switchboard shall have current-carrying parts above 7500 volts exposed (unguarded) unless these parts are effectively isolated by elevation, except at times when occasionally left exposed by removal of covers or entrance into inclosures, such as switch and instrument transformer cells or compartments, which are ordinarily unoccupied by persons. For such parts, if exposed while alive for any purpose (including busses and disconnectors in compartments), working space shall be provided complying with the requirements under rule 169 *d*.

Sec. 18. LIGHTNING ARRESTERS

180. Location

Lightning arresters when installed inside of buildings should be located as far as practicable from all other equipment and from combustible parts of the building.

181. Provisions for Disconnecting

(*a*) Lightning arresters on circuits over 7500 volts shall be so arranged, isolated, and equipped that they may be readily disconnected from conductors to which they are connected by air-break manual disconnectors, having air gaps of not less than four times the equivalent needle point sparking distance of the operating voltage of the circuit to which the arresters are connected, and never less than eight inches.

(*b*) Such disconnectors, unless remotely controlled and operated, shall have the adjacent working spaces required by rule 169 *d*, for disconnectors generally.

182. Ground Wires

Ground wires shall be run as directly as possible and be of low resistance and ample current capacity. (See sec. 9.)

183. Grounding Frames

All noncurrent-carrying metal parts of arresters shall be grounded, unless effectively isolated by elevation, or guarded as required for live parts of the voltage of the circuit to which the arrester is connected, and suitably identified as of that voltage.

184. Guarding Live Parts

(*a*) All current-carrying parts of arresters on circuits above 750 volts, unless effectively isolated by elevation, shall be adequately guarded to protect persons from inadvertent contact with them, or from injury by arcing.

(*b*) Lightning arresters, unless provided with disconnectors which are always opened before work is done on the arresters, shall be so arranged that necessary adjustments are possible (without approach to current-carrying parts) through the use of permanently grounded mechanisms or suitable insulating appliances. Where charging or adjustments must be made with arresters alive, permanently grounded mechanisms or suitable insulating appliances shall always be provided.

(*c*) Guarding shall comply with the provisions of rules 115 and 152.

185. Utilization Installations

Lightning arresters when installed for the protection of utilization equipment may be installed on supply lines or service leads either within or without the buildings or inclosures containing the equipment to be protected, and the methods employed shall be in accordance with the rules governing the construction of overhead lines, supply stations, or utilization equipment, as they apply.

DISCUSSION OF PART 1

Sec. 10. PROTECTIVE ARRANGEMENTS OF STATIONS AND SUBSTATIONS

100. Scope of the Rules

A somewhat less general use of guards and less complete isolation is, of course, allowable with station equipment, because of the more expert attendants in stations, than is allowable with electrical utilization equipment exposed to contact of attendants and others more or less unfamiliar with electrical hazards, these being the conditions usually in workshops, mercantile establishments, electrically propelled vehicles, and other places where machinery and apparatus utilizing electrical energy are installed.

101. Application of the Rules

(*a*) The rules are intended to be observed completely in new work under ordinary conditions and suitable alternatives, based on the practicability of enforcement of the rules, are provided so that no hardship should result from their intelligent administration. 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.

(*b*) 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 over 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.

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*) 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.

(*b*) 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.

(*c*) 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.

103. Illumination

(*a*) 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 arrangement 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 managment) the use of long cords attached to distant receptacles and hauled over floors and about equipment.

(*b*) 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 specially 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.

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

104. Inclosing Walls and Ceilings

(*a*) To assure against service interruption and against injury to both equipment and trespassers, entrance of the latter should be prevented by use of suitable inclosing walls or fences. By this protection, also, the attendant is safeguarded against dangers arising from distraction of his attention. Locking entrances is recommended and frequently practiced for the same reasons.

(*b*) Where outdoor substations are located near high factory buildings, wire nettings may be so placed as to prevent injury to the equipment by flying or falling objects.

105. Floors, Floor Openings, Passageways, and Stairs

(*a*) Falls, hitting obstructions, and similar mechanical accidents are responsible for the greater proportion of all personal injuries in stations.

(*b*) Passageways or working spaces only infrequently occupied, such as bus bar or pipe chambers under floors, may with reasonable safety have less than 6.5 feet clear headroom, since inadvertent movements are less liable to be made in such places.

(*c*) 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 exist is a desirable practice, and many companies use them where the difference in level is much less than that for which a railway is required by the rule.

(*d*) 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.

106. Exits

(*a*) 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 repair.

(*b*) 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 cut 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.

107. Fire Fighting Appliances

The use of sodium carbonate 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.

Sodium carbonate 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 having apparently proven more reliable in practice than those depending in any way on air pressure.

Sec. 11. PROTECTIVE ARRANGEMENTS OF EQUIPMENT

110. General Requirement

In general, it is recommended that such rules of the National Electrical (Fire Prevention) Code as apply, be complied with in the arrangement and protection of equipment and circuits, when not conflicting with these rules. In general, those rules, by reducing fire hazard, also indirectly reduce the life hazard.

111. Inspections

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

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 avoid overlooking them. The recording of defects also tends to improve design in new installations or extensions. Cleanliness, of course, retards deterioration.

112. Infrequently Used Equipment

Equipment seldom used is frequently neglected and so may be dangerous whenever placed in service. This can be avoided by systematic inspection.

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

113. Protective Grounding

(*a*) The grounding of equipment for protection of persons must be thoroughly reliable, or 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*) 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, this is, of course, 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.

(*c*) 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 protected 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 ungrounded 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.

114. Working Space About Electrical Equipment

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

Working spaces can be made inaccessible to unauthorized persons while remaining accessible to authorized persons by setting apart spaces under constant supervision of the attendant, and by fencing or otherwise inclosing working spaces not under his immediate supervision. Even the space under supervision, preferably, should be inclosed by a guard rail. In either case conspicuous warning signs should be erected, prohibiting entrance of unauthorized persons.

(*b*) The spaces specified should be considered as minimums and increased where practicable. The danger from shocks increases as voltage increases. Parts above 7500 volts unless isolated by elevation, or only infrequently approached, should by rule 115 be normally incased, even where adjacent to liberal working spaces accessible only to authorized persons, and provided with suitable insulating floors, mats, or platforms. Below 7500 volts, reliance may usually be placed on provision of liberal space for the attendant, good footing, and careful instruction. Even with voltages above 7500 it is necessary to provide for occasional approach to live parts, such for instance as disconnecting switches, by removal of compartment covers. The special precautions and space requirements for such cases are given in rule 169 *d*.

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 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 such spaces. It is necessary, with long passageways, to recognize the inability of persons to walk without some variation from a straight line and to keep in mind the nervousness which may result from knowledge of the exposed live parts at both sides.

115. Guarding Live Parts

(*b*) 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 so as to permit necessary inspection, ready access, and quick repair or adjustment. Quick access is an essential to avoid unnecessarily slowing-down operation in emergencies of service. Liberal working spaces are always to be recommended for the safety of the workman as well as for promoting continuity of service.

(*c*) For lower voltages use of insulating floor coverings prevents the most frequent and dangerous form of electrical shock, that of a circuit through the entire body from hand to foot. (See also Discussion of rule 306.)

(*d*) For very high voltage parts, however, reliance on space is insufficient, and elevation or guarding must be resorted to, in order to prevent hand-to-hand as well as hand-to-foot circuits.

If carefully planned, permanent guards should aid rather than delay service, by making possible, with safety, repairs near live parts which would otherwise require shutting down adjacent circuits or use of makeshift protective devices. Such guards also should tend to prevent accidental short circuits by tools, and the spread of short circuits beyond the place of origin.

Such inclosures or barriers are particularly necessary where, from the nature of the situation, dry insulating floors are impracticable, or where obstructions necessarily make the floor an insecure footing. Low walls or ridges either across a pathway, or beside it, increase the liability to stumbling, especially when attention must be given to other surrounding dangers, such as the live exposed parts.

(*e*) Covers for meters, inclosing cases for switches, and complete inclosure of terminals are among such guards as are suitable for live parts above 7500 volts. In some cases, barriers extending beyond live parts on the accessible side, may sufficiently prevent inadvertent contact of persons or objects.

116. Isolating Live Parts by Elevation

Live parts over the heads of persons are subject to contact only by persons placing themselves on chairs, stools, or ladders, or raising arms or tools above their heads. None of these actions are ordinarily considered as being done inadvertently by properly qualified persons, who alone should be authorized to work in spaces having exposed live parts above them. As the danger of serious injury increases (at least up to a certain point) with the voltage, higher clearance seems necessary as voltage increases, as it seems more important with higher voltages to take into consideration the possibility of persons inadvertently raising arms above their heads, thereby increasing their effective height by a foot or more.

Beyond a certain voltage, too, the sparking distance becomes a factor, and with any such voltages it is advisable to consider the arms as fully raised, and to add a multiple of the sparking distance to the 7 or 8 feet effective height of a person. It is probable that the elevations of live parts at different voltages, as required in the rule, are a very small minimum when all these points are considered, and greater elevations should be secured if available space will permit. Very tall persons will find the elevations insufficient, but it is intended that the person of average height, observing due precaution, shall be reasonably safeguarded.

117. Identification

The ability to readily 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 they 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. Labelling 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 cut-outs.

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.

Sec. 12. ROTATING EQUIPMENT

120. Speed-Control and Stopping Devices

(*a*) The importance of automatic speed-limiting devices for certain types of prime movers is becoming better realized. More cases of rotating parts failing by overspeed occur than of boiler explosions, which are so seriously regarded. With steam turbines and belted water turbines such limiting devices are particularly needed. Even reciprocating engines are frequently fitted with extra valves and independent speed-limiting mechanisms. Water turbines in many cases have deflecting nozzles or vanes, usually operated by the governor, which serve to prevent overspeed. Generators driven by prime movers carry a load which may become nearly zero by the opening of automatic cut-outs. The speed-limit device may therefore need to be very quick acting, and yet in cutting off the steam or water supply from the engine or turbine must not cause any damage to the feeder piping.

(*b*) 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, 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 cut-outs, the danger of overspeeding is considerable. Centrifugal devices which at high speeds actuate trip devices for opening the source of energy supply are most often utilized as means of protection against such a contingency.

(*c*) With direct-current motors having speed adjustment through field control, dangerously weak fields must be avoided, since excessive speed may result from this cause, especially when the load is belt-connected to the motor or consists of generators. Release coils, whether placed on starting rheostats or otherwise, in which the field circuit passes through the coil, are among useful means for preventing the dangerous weakening of fields during operation. In some cases centrifugal speed-limiting devices are installed.

(*d*) 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.

(*e*) 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 closed circuits assures that any chance open circuit will immediately give evidence of its existence 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, it will be necessary to depend on the mechanical protection of the circuit for its maintenance in operative condition.

121. Protecting Shaft Ends, Pulleys, Belts, and Other Moving Parts

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 slightly moving parts. However, projecting set screws, for instance, may be dangerous even on such slow or small parts. Detailed requirements for guarding of moving parts of all kinds have been adopted by casualty companies and associations and by State industrial commissions for application to all occupancies where such mechanical hazards exist, and it seems undesirable to repeat such requirements in these electrical rules.

122. Guards for Live Parts

With 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, since shocks frequently occur due to contact with live parts by persons who are also touching other conducting parts in the vicinity.

In some cases insulating screens or other shields, adjacent to the grounded frame or other grounded parts which would be otherwise exposed to contact, would be advisable to protect persons who may necessarily be engaged in the adjustment of brushes, or other live parts, where these parts are ordinarily guarded and dependence is usually placed on insulating mats or platforms for protection of persons. In general, the continuous insulating cover on conductors and machine windings above 750 volts should not be regarded as a suitable inclosing guard, where exposed to mechanical injury or to dampness. Substantial guards are conduit, metal casings and shields of equipment, fencing, or similar inclosures.

123. Hazardous Locations

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 located in adequately ventilated, separated rooms or compartments or otherwise be 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, a completely explosion-proof casing should be used. 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 and dry-cleaning establishments 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.

124. Grounding Noncurrent-Carrying Parts

(*b*) 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. The reason for omitting the ground connection is usually that insufficient insulation is provided between the current-carrying parts and the frame to permit of reliable operation were the ground connection made. Insulating mats or platforms are therefore more than ever necessary about such machines, since their frames may become alive through leakage at any time.

(*c*) 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. Where practicable, insulating barriers should be installed to prevent persons from inadvertently touching both frames simultaneously.

(*d*) 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 1200 or 2400 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 1200 or 2400 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 dangers and difficulties which may be entailed by omitting ground connections from exposed cases and frames of equipment operating at high voltages.

125. Deteriorating Agencies

Any hastening of deterioration of electrical equipment by moisture or uncleanliness means greater danger of breakdown of insulation, which 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 in oil-insulated transformers and switches often rapidly deteriorate and endanger attendants who may come in contact with these leads, relying on their insulating coverings as a guard. (Compare rule 115 *b*.)

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 such equipment should be made inaccessible, except to qualified persons, and placed in a room or compartment away from other equipment, if the size of the battery is such as 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 sufficiently reduce the inflammable gas accumulations. Pockets in ceiling spaces above door and window openings should be avoided.

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 sufficient. 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

Separate insulating supports for cells prevent current leakage along surfaces from one cell to another, which might result in dangerous arcing or making adjacent floors alive. Drainage of floors also reduces the danger of shock and retards deterioration of battery and building alike.

133. Guarding Live Parts in Battery Rooms

(*a*) 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.

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.

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, REACTANCES, INDUCTION REGULATORS, BALANCE COILS, AND SIMILAR EQUIPMENT

Oil-insulated and similar equipment of the larger sizes should, where practicable, be well spaced from other equipment, and groups of such equipment should be subdivided by fire-resistive barriers or walls. It is preferable to place the larger transformers in a room containing no other equipment except necessary controlling or protective equipment and connections.

Drainage should be provided so that cases and rooms may be emptied of oil very quickly, especially where other equipment is exposed or where any portion of the station structure is combustible. Arrangement is often made so that control of energy supply and drainage can be operated from a point outside the room containing the oil insulated equipment. Door or window openings which communicate from transformer rooms to rooms containing other equipment should be fitted with tight fire-resistive doors or windows, and all openings near the floor line of transformer rooms should be provided with oil-tight sills of suitable height to retain any overflowing oil.

140. Current Transformer Secondary Circuits

(*a*) 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*) All such secondary circuits should be so installed 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.

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 ungrounded 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 which are more or less grounded.

143. Transformers

(*a*) 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.

(*b*) 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 under 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 separate room is usually desirable. Where the transformers operate at over 750 volts, such 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 separate room if such other guarding can be made as effective and the amount of oil used for insulation does not necessitate the use of separate room to prevent excessive fire hazard.

Sec. 15. CONDUCTORS

150. Electrical Protection

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 other suitable 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 cut-outs.

The danger to consumers, however, by interruptions to service may (in the instances named as exceptions to rule 150 *a*) be still more serious, since theater emergency lighting, elevators, hospital operating lamps, and similar vitally necessary service may be dependent on the supply. Persons are unlikely to be near underground feeders unless they are authorized, in which case they can observe extra precautions, if no automatic protection against overloads has been installed.

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.

151. Mechanical and Thermal Protection

Usually the insulating covering of a conductor is not to be relied on as a mechanical protection. Its function is to provide insulation and it should, therefore, be protected against any mechanical injury so that its value as insulation will remain undiminished. Even if well insulated, a conductor may be dangerous through the existence of a charge on its exterior surface, especially where flame-proofing material is used which is not insulating and where the voltage of the conductor is relatively high.

Where conductors are necessarily grouped rather closely the danger from fires spreading becomes considerable, unless the insulation is incapable of supporting combustion.

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, such flame-proofing compounds or braids that are at all conducting must of course be stripped away from the bare terminal.

In case of severe overloads, adjacent conductors have been seriously damaged by the repulsive effect of their magnetic fields.

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 nearly equivalent to actual guarding by casing or armor.

153. Guarding Conductors

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 duct, although not strictly fire-resistive, may be included among suitable ducts. If several are grouped together, some further fireproofing should be utilized.

Above 750 volts additional protection is necessary to protect persons from contact with conductors. An exterior grounded metal sheath or conduit is usually the best protection. 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.

154. Guarding in Hazardous Locations

(*a*) The slightest arcing at bad joints in 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 in the conduit or at a point where the insulation is defective between one of the conductors and the conduit itself.

(*b*) 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. Pendants and Portables

The use of long cords and of cords attached direct to bus bars, switch terminals or blades, and similar makeshifts is frequently the cause of severe 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.

156. Temporary Wiring

The tendency to install unsubstantial wiring with the expectation of soon correcting the defects, is responsible for the existence of much defective wiring in existing installations. Such "temporary" wiring often remains for years, offering more or less menace to service and to operators, whereas the additional cost and time which would have been required to make the installation standard would have been inconsiderable.

On the other hand, there is a legitimate use for "temporary" wiring for testing or similar work where the equipment is under competent supervision when it is alive.

Sec. 16. FUSES AND OTHER CUT-OUTS; SWITCHES AND CONTROLLERS

160. Accessible and Indicating

Switches and other control or protection equipment should be very convenient to the operator, as no other part of the station installation is so much adjusted while alive 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. Sometimes marking, in addition to orderly arrangement, is advisable to show the function of switches or fuses.

161. Hazardous Locations

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 which may result from gas contained in them without emitting gasses at a temperature which can ignite inflammable gases without. Air-tight cases or cases with carefully screened passages have been developed to meet such conditions

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 without special precautions on such equipment, unless both parts are disconnected from the source of energy, while if a person comes accidentally in contact with live or moving parts of either equipment the operation of a single switch will disconnect both from the source of energy.

163. Switches or Other Grounding Devices

Since it is necessary, particularly with high-voltage parts, to protect workmen by short circuiting and grounding parts to permit work to be readily done upon them, it is advisable that permanent means be provided in stations to facilitate the use of this protection. The similar short circuiting and grounding of lines will, of course, require more readily portable devices.

164. Character of Switches and Disconnectors

(*a*) The capacity of a switch, when it must be operated under load, should be proportioned to the load which it is liable to be required to interrupt. If no automatic cut-outs are in service, and the design of the system does not provide other means to closely limit the current, the switch should in general be automatic, and arranged to operate before the current rises unduly or 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 should nevertheless be capable of carrying full current of the circuit and should be suitably identified as disconnectors. It is important where a number of disconnectors are placed together that they should be carefully distinguished by suitable markings so that the wrong disconnector will not be accidentally opened.

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 arrangement should be provided so that switches can be locked or blocked in the open position.

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.

165. Where Automatic Cut-Outs are Required

Except where greater hazard might be caused by the opening of circuits automatically than by the overloads and short circuits which may persist until manually interrupted where automatic cut-outs are not provided, the latter protection should always be afforded to equipment and circuits. With certain types of circuits, however, the use of automatic cut-outs operating on overloads is relatively unnecessary. Distributed resistance or reactance or suitable regulators might satisfactorily limit the possible currents in circuits from generators or batteries in some cases. Series arc light circuits are examples of circuits limited by their design to a certain maximum current.

166. Disconnection of Fusible Cut-Outs 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 danger of receiving burns while replacing a fuse in a live clip through the blowing of the fuse by short circuits beyond it is a serious one. 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.

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 so located 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 and Automatic Cut-Outs

(*a*) 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 so arranged 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.

(*b*) 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 reasonably protected against slipping into contact with the live part 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.

(*c*) 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 incased during operation, even although insulating handles are provided, insulating floor protection should also be provided where switches operate at over 300 volts to ground.

(*d*) 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 adjusted, 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.

Sec. 17. SWITCHBOARDS

170. Accessibility and Convenient Attendance

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 take other positions from which he is liable to slip or fall against live parts.

171. Location and Illumination

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. 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 note on rule 103.)

172. Necessary Equipment

Ground detectors giving continuous indication are recommended for all 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. In the same way, ammeters are usually necessary to indicate the existence of overloads or short circuits and should always be used where the circuit is not protected against these conditions, and the public and operator against the danger imposed, by suitable automatic cut-outs in circuit or by protective features in the design of the system.

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.

174. Spacings and Barriers Against Short Circuit

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. Generally speaking, 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. Grounding

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

(*a*) 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, of course, accomplishes the same purpose.

(*b*) 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 clean, dry surroundings usual with switchboards, afford effective protection to the operator should he accidentally touch one live part of even moderately high voltage. Various materials, such as albarene 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 are flush with the floor surface.

(*c*) The danger of injury from contact with two live parts between which a voltage over 750 exists or from contact with one live part and ground where the part is operating at over 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 below 750 volts the danger from flashes and contact may be considerable and isolation is recommended for unguarded parts in new construction, 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 somewhat above 750.

(*d*) 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, the use of suitable guard rails or partitions should be provided. Even with liberal working spaces, such guard rails or partitions are to be recommended as likely to protect attendants from injuries by inadvertant movements while near the switchboard.

(*e*) 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.

(*f*) 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. Very high voltage parts exceeding 7500 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 even adjustment. At these intervals, 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 that live parts at these high voltages may be made dead before they are approached in an unguarded condition should it be permissible to dispense with the liberal working spaces called for under the rule.

Sec. 18. LIGHTNING ARRESTERS

180. Location

Lightning arresters have been frequent causes of fires where located near combustible portions of buildings. 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 otherwise 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

To safely accomplish the necessary cleaning and inspection of arresters on high voltage circuits, particularly above 7500 volts, their disconnection from the live circuit is necessary and such disconnection is, of course, desirable even for lower voltages.

Part 2.—RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRICAL SUPPLY AND SIGNAL LINES.

CONTENTS

OVERHEAD AND UNDERGROUND LINES

Sec. 20. GENERAL PROTECTIVE REQUIREMENTS

200. Scope of the Rules

(*a*) The following rules apply to electrical supply and signal lines in overhead and underground construction, whether operated in connection with public utilities, privately or municipally owned, industrial establishments, or otherwise.

(*b*) These rules are not intended as complete specifications for overhead and underground line construction, but are intended to embody the requirements which are most important from the standpoint of safety to employees and the public.

(*c*) Construction should be made according to accepted good practice for the given local conditions in all particulars not specified in the rules. They cover both transmission and distribution lines, and the special construction needed for crossings, conflicts, and common use of poles.

201. Application of the Rules and Exemptions

(*a*) The rules are intended to apply to all installations except as modified or waived by the proper administrative authority, or its authorized agents, and are intended to be so modified or waived in particular cases, whenever any rule is shown to involve expense not justified by the protection secured, or for any other reasons to be impracticable; or whenever it is shown that equivalent or safer construction can be more readily provided in other ways.

(*b*) The intent of the rules will be realized: (1) By applying the rules in full to all new installations, reconstructions, and extensions, except where any rule is shown to be impracticable, for special reasons, or where the advantage of uniformity with existing construction is greater than the advantage of construction in conformity with the rules; (2) by placing guards on existing installations or otherwise bringing them into compliance with the rules, except where the expense involved is not justifiable.

The time allowed for bringing existing installations into compliance with the rules as specified in (2) will be determined by the proper administrative authority.

(*c*) It will sometimes be necessary to modify or waive certain of the rules in cases of temporary installations or installations which are soon to be discarded or reconstructed.

(*d*) In cases of emergency or pending decision of the administrator, the person responsible for the installation may decide as to modifications or waiver of any rule, subject to review by proper authority.

202. Design and Construction

All electrical supply lines and equipment shall be of suitable design and construction for the service and conditions under which they are to be operated, and all lines shall be so installed and maintained as to reduce the life hazard as far as practicable.

203. Minimum Requirements

The requirements of these rules as to spacings, clearances, and strength of construction are minimum requirements. More ample spacings and clearances or greater strength of construction than the specified minimum may be provided, if other requirements are not neglected in so doing.

204. Inspections and Tests

(*a*) Electrical lines and their equipment shall comply with these safety rules when placed in service, and shall thereafter be systematically inspected by the person responsible for the installation and, when necessary, subjected to tests to determine their fitness for service. Any defects revealed by such inspection shall be recorded, if not promptly corrected. Defective lines and equipment shall be put in good order or effectively disconnected. Lines permanently abandoned, which may create a hazard, shall be removed.

Overhead service loops to consumers are often disconnected without removal when the service is discontinued. This is considered good practice where it is undesirable to remove the service loop entirely.

(*b*) Lines temporarily out of service shall be maintained in such condition that a hazard will not be created. Infrequently used supply lines and their equipment shall be inspected to determine whether they are in safe condition for service.

205. Isolation, Guarding, and Accessibility

(*a*) Current-Carrying Parts.—To promote safety to the general public and to employees not authorized to approach conductors and other current-carrying parts of electrical supply lines, such parts shall be so arranged as to provide adequate clearance from the ground or other space generally accessible, or shall be provided with necessary guards so as to effectively isolate them from accidental contact by such persons.

(*b*) Guards and Warning Signs.—If the supply conductors exceeding 300 volts to ground are carried on poles stepped nearer than 6.5 feet from the ground or from other readily accessible space, or on closely latticed poles or towers, guards or warning

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signs should be used except on fenced rights-of-way to protect against careless approach to the conductors by unauthorized persons, except that on poles carrying signal cable or twisted pairs below supply conductors, a wood block on one side only of the pole may be placed not less than 3.5 feet from the ground or other readily accessible place without necessitating the use of guards or warning signs.

(*c*) NONCURRENT-CARRYING PARTS.—In urban districts, ungrounded metal sheathed service cables, service conduits, metal fixtures, and similar noncurrent-carrying parts, where liable to become charged to over 300 volts to ground (see rule 207 *b* and 252 *h*) shall be so isolated or guarded as not to be exposed to accidental contact by unauthorized persons.

Metal poles not guarded, isolated, or specially grounded, should always be considered as imperfectly grounded, and the insulators supporting line conductors as well as the strain insulators in attached span wires should therefore have a suitable margin of safety and be maintained with special care, to prevent leakage to the pole as far as practicable.

Metal poles not guarded or isolated shall always be specially grounded where in contact with metal sheathed cable or metal case of equipment operating at over 750 volts.

(*d*) ACCESSIBILITY.—All parts which must be examined or adjusted during operation shall be so arranged as to be readily accessible to authorized persons, by the provision of adequate clearances between conductors and of adequate climbing and working spaces and facilities.

206. Arrangement of Switches

All switches shall be readily accessible to authorized persons and shall indicate clearly whether open or closed.

To minimize operating errors the handles or control mechanism for switches, should, as far as practicable throughout any system, have the same position when open, and a uniformly different position when closed. Where it is advisable to depart from this practice the switches should be so marked as to minimize the liability to mistakes in operation.

207. Grounding Circuits and Equipment

(*a*) All lighting arrester grounding, except for signal circuit arresters, and all grounding of circuits, equipment, or wire runways, which is intended to be a permanent protective measure shall be done in accordance with the methods specified in section 9. (For signal circuit arrester grounding, see rule 393.)

(*b*) In urban districts metal conduit, cable sheaths, frames, cases, or hangers of equipment not effectively guarded from accidental contact of other than properly qualified workmen shall, if nearer than 8 feet to the ground, be permanently grounded, except metal conduit and cable sheaths inclosing conductors of not over 300 volts to ground and not exposed to probable contact with overhead conductors of over 300 volts to ground. (See rule 205 *c*).

Metal conduit above ground, where containing extensions from underground metal-sheathed cable, is considered as sufficiently grounded by the sheath, if the sheath itself is in good contact with earth. (See sec. 9). It is recommended that supply cables have the sheath bonded to any conduit extending above the ground surface.

208. Identification of Conductors and Poles

(*a*) All conductors and equipment of electrical supply and signal lines should be arranged to occupy definite positions throughout, as far as practicable, or shall be so constructed, located, marked, or numbered as to facilitate identification by employees authorized to work thereon. This does not prohibit systematic transposition of conductors.

(*b*) Poles, towers, and other supporting structures on which are maintained electrical conductors shall be so constructed, located, marked, or numbered, as to facilitate identification by employees authorized to work thereon. Date of installation of such structures shall, where practicable, be recorded by the owning utility.

OVERHEAD LINES

Sec. 21. GRADES OF CONSTRUCTION REQUIRED FOR CROSSINGS, AND OTHER CONDITIONS OF HAZARD

210. Required Grades of Overhead Line Construction, and Arrangement of Levels

(*a*) Various Conditions of Hazard.—Supply and signal lines (1) when concerned in crossings or conflicts, (2) where carried on the same supports with other lines, or (3) where carried through urban districts, shall have mechanical construction of the grade designated as A, B, C, D, or E, according to the hazard involved. The conditions determining each grade of construction are defined in the following paragraphs. Where none of these conditions exist, no specific grade of mechanical construction is required. Grades of construction A, B, and C are specified in the rules of sections 22 and 23. Grades of construction D and E are specified in section 28. In any case where two or more of the conditions listed below exist, the grade of construction shall be the highest called for under any item applying.

(*b*) Arrangement of Relative Levels.—Where supply and signal lines or supply lines of different voltage classification cross each other or are in conflict, or are on the same poles or towers, the higher voltage lines shall preferably be carried at the higher levels (see rule 270 *b*).

(*c*) Signal Lines not for Public Use.—Signal lines not for public use shall be regarded as in any one of the following classes:

(1) Signal lines for public use, so far as their own construction and that of neighboring supply lines is concerned.

(2) Supply lines of the highest voltage to which they are exposed (with a limit of 7,500 volts), so far as their own construction and that of neighboring supply and signal lines is concerned, but not always as to wire sizes (see rule 221 *e*).

(3) Signal lines for public use so far as their own construction is concerned, but not requiring any special construction precautions on the part of neighboring supply or signal lines. In lieu of this, if exposed by supply lines at higher levels, they shall be protected by lightning arresters or other devices which will prevent their voltage to ground from normally exceeding 400.

The rules referring to signal lines in all cases refer to signal lines for public use, and their application to signal lines not for public use is determined by that one of the above construction methods applied to the signal lines and to neighboring lines. The method chosen shall be consistently adhered to throughout the extent of the signal system.

211. Supply Lines Crossing over Railways. (See sec. 26)

Supply lines carried over railways, operated by steam, electric, or other motive power, except as provided in rule 212 below, shall conform to the construction requirements of grade A.

212. Supply Lines Crossing over Unimportant Railways. (See sec. 26)

(*a*) Supply lines carried over sidings not exceeding four tracks, or over spurs, or over branches or other unimportant railways operated by steam, electric, or other motive power, shall, with the exception noted in (*b*) below, conform to the construction requirements of grade B.

Unimportant railways generally are those having not more than a single parallel signal circuit. Signal circuits carried over a different right of way for part of their route, but concerned in the operation of the railway line, are included as parallel signal circuits, within the intent of this paragraph.

(*b*) Supply lines carried over street railways, which are on traveled portions of highways, need conform only to the general requirements of sections 22 and 23 for supply lines other than those of grades A, B, and C and to the construction requirements of rules 217, 218, and 219 where they apply, the trolley contact conductor being considered for the purposes of this rule as a supply conductor of equal voltage. (See rule 273.)

213. Signal Lines Crossing over Railways. (See sec. 28)

(*a*) Telephone, telegraph, and other signal lines carried over railways operated by steam, electric, or other motive power shall, with the exceptions noted below, conform to the construction requirements of grade D, as given in section 28.

(*b*) Signal lines carried over sidings not exceeding four tracks, or over spurs or over branches or other unimportant railways operated by steam, electric, or other motive power, shall conform, except as noted below, to the construction requirements of grade E, as given in section 28.

(*c*) Signal lines carried over street railways not having overhead trolley contact conductors exceeding 750 volts, where such street railways are located on traveled portions of highways, need conform only to the general construction requirements of section 28 for signal lines in these situations.

(*d*) Signal lines carried over electric railways having overhead trolley contact conductors above 750 volts shall conform to the construction requirements of grades A, B, or C, according as the conditions listed in rules 214, 215, or 216 apply.

(*e*) Signal lines which have assumed the character of supply lines shall, where crossing over railways, conform to the construction requirements of rules 211 or 212, according to the character of the railway concerned. (See rule 210 *c*.)

214. High Voltage Supply Lines in Crossings, Conflicts, and Common Use of Poles with Signal Lines. (See secs. 26 and 28)

(*a*) Constant-potential alternating-current supply lines of over 7500 volts, or constant-current circuits exceeding 10 amperes, or direct-current grounded trolley circuits of over 750 volts, where at higher levels and crossing over or conflicting or on common poles with telephone, telegraph, or other signal lines shall conform to the construction requirements of grade A, except as noted below:

(1) It is not intended that this requirement shall apply to supply lines at higher levels than signal lines, where over individual twisted pair drop wires only, or where over other unimportant circuits only, if equally effective protection is secured by other methods of construction.

(2) Where the signal line is at a lower level than the supply line and carries not more than four wires used mainly for local exchange service, or carries only subscribers' loops, or carries not more than two unimportant commercial telegraph wires, grade B may be used for the supply line.

(*b*) Signal lines, carried at higher levels than the supply lines listed in (*a*) above, in crossings, conflicts, or common use of poles, shall be of the grade of construction required in (*a*) for the supply lines. (See also rule 210*c*.)

215. Medium Voltage Supply Lines in Crossings, Conflicts, and Common Use of Poles with Signal Lines. (See secs. 26 and 28)

(*a*) Constant-potential alternating-current supply lines of between 5000 and 7500 volts, or constant-current circuits of between 7.5 and 10 amperes, where at higher levels and crossing over or in conflicts or on common poles with the telephone, telegraph, or other signal lines shall conform to the construction requirements of grade B, except as noted below.

It is not intended that this requirement shall apply to supply lines at higher levels than signal lines, where the latter are individual twisted pair drop wires only, or where over other unimportant circuits only, if equally effective protection is secured by other methods of construction.

(*b*) Signal lines carried at higher levels than the supply lines listed in (*a*) above in crossings, conflicts, or common use of poles shall be of the grade of construction required in (*a*) for the supply lines. (See also rule 210*c*.)

216. Low Voltage Supply Lines in Crossings, Conflicts, and Common Use of Poles with Signal Lines. (See secs. 26 and 28)

(*a*) Constant-potential alternating-current supply lines between 750 and 5000 volts, and constant-current circuits not exceeding 7.5 amperes, in urban districts, where at higher levels and crossing over or conflicting with or on common poles with signal lines shall conform to the construction requirements of grade C, except as noted below.

It is not intended that this requirement shall apply to supply lines at higher levels than signal lines, where over individual twisted pair drop wires only, or where over other unimportant circuits only, if equally effective protection is secured by other methods of construction.

(*b*) Signal lines carried at higher levels than the supply lines listed in (*a*) above, in crossings, conflicts, or common use of poles shall be of the grade of construction required in (*a*) for the supply lines, except as smaller wire sizes are permitted by rule 221. (See also rule 210*c*.)

217. Supply Lines above 7500 Volts in Urban Districts. (See sec. 27)

Constant-potential supply lines and constant-current circuits over 7500 volts in urban districts, where alone (except on fenced rights of way), or where crossing over, or in conflicts, or on common poles, with other supply lines or constant-current circuits, shall conform to the construction requirements of grade B.

218. Supply Lines of 750 to 7500 Volts in Urban Districts. (See sec. 27)

Constant-potential supply lines and constant-current circuits between 750 and 7500 volts in urban districts where alone (except on fenced rights of way), or where at higher levels and crossing over, or in conflicts, or on common poles, with supply lines or with constant-current circuits under 7500 volts, shall conform to the construction requirements of grade C. If the other circuits concerned exceed 7500 volts grade B is required.

219. Supply Lines above 7500 Volts in Rural Districts. (See sec. 27)

(*a*) Supply lines or constant-current lines above 7500 volts in rural districts at higher levels and crossing over, or in conflicts, or on common poles with supply lines not exceeding 750 volts shall conform to the construction requirements of grade C.

(*b*) Supply lines above 7500 volts are exempted from this requirement if crossing over or conflicting with only service connections from supply lines.

(*c*) Supply lines below 750 volts in rural districts at higher levels and crossing over, or in conflicts with, or on common poles with lines exceeding 7500 volts shall conform to the construction requirements of grade C.

Sec. 22. LOADING ASSUMPTION AND SAGS OF CONDUCTORS

220. Basis of Stress Calculations [2]

In the calculation of all stresses no allowance shall be made for deformation, deflection, or displacement of any part of the supporting structures. The effect of certain influences which diminish the effective stresses resulting from the assumed loadings has received careful consideration by reducing (below what would otherwise be considered proper) the assumed loadings upon which are based the strength requirements of the several parts of the

[2] A discussion of the influences affecting the assumptions as to stresses in conductors and supports will be given in a later Bureau publication.

line—namely, conductors, fastenings, and pole or tower structures. (See also rule 230 *a*.)

221. Conductors—Material and Minimum Sizes

(*a*) All supply conductors, all signal conductors carried above trolley-contact conductors, and all conductors of grades A, B, C, D, or E shall be of copper, aluminum with or without steel reinforcement, copper-covered steel, or other material which will not corrode excessively under the prevailing conditions.

(*b*) No wire smaller than No. 6 if soft copper, No. 8 if hard or medium copper, nor less than No. 9 (Stl. W. G.) if steel shall be used for supply lines in urban districts. It is recommended that these minimum sizes shall not be used in spans longer than 150 feet in heavy loading districts and 175 feet in medium and light loading districts. (See rule 242 for increase of conductor separation as sag is increased.)

(*c*) Aluminum or steel-reinforced aluminum conductors shall be stranded. Without reinforcement the size in urban districts shall be not less than No. 1, and not less than No. 0 for spans over 150 feet. With reinforcement the size in urban districts shall be not less than No. 6, and not less than No. 4 for spans over 150 feet.

(*d*) Service-supply leads shall not be less than No. 10 if soft copper, No. 12 if hard or medium copper, or less than No. 12 (Stl. W. G.) if steel. If spans exceed 150 feet, a larger size is required. (See rule 273 *b*.)

(*e*) Conductors of signal lines of grades A, B, and C construction (see rules 214, 215, and 216) shall be of not less than the minimum sizes required for supply lines of the same grade (see rule 223 *e* and the paragraphs above), except that for signal lines of grade C construction (see rule 216) and for signal lines which have become supply lines of grade C construction (see rule 210 *c*).

No. 10 hard copper or steel is permitted when the sags are not less than 12 inches for spans not exceeding 100 feet, and when the sags are not less than 18 inches for spans not exceeding 125 feet, and No. 9 is permitted when the sags are not less than 27 inches for spans not exceeding 150 feet.

(*f*) Lightning protection wires shall be regarded, in respect to size and material requirements, as supply conductors.

222. Loads Assumed in Determining Stresses in Conductors

(*a*) In computing the longitudinal stresses upon conductors and their supports, and the sags corresponding to given limiting stresses in conductors, the loading shall be assumed to be one of the following, according to climatic conditions of the locality concerned. Lightning protection wires are to be regarded, in respect to these mechanical requirements, as supply conductors.

(1) Heavy Loading (H).—The resultant loading at 0° F, due to the weight of the conductor plus the added weight of a layer of ice one-half inch in radial thickness, combined with a transverse horizontal wind pressure of 8 pounds per square foot on the projected diameter of the ice-covered conductor, shall be called heavy loading.

(2) Medium Loading (M).—The resultant loading at 15° F, due to wind and the weight of the conductor and ice, equal to two-thirds that specified in (1) above, but in no case less than 25 per cent in excess of the weight of the conductor, shall be called medium loading.

Only with copper conductors of 400 000 circular mils or larger size or with very large conductors of other material is the resultant loading less than 25 per cent in excess of the conductor weight.

(3) Light Loading (L).—The resultant loading, at 30° F, due to wind and the weight of the conductor, equal to two-thirds that specified in (2) above or four-ninths that of (1), but in no case less than 25 per cent in excess of the weight of the conductor, shall be called light loading.

Only with copper conductors of No. 000 or larger size or with very large conductors of other material is the resultant loading less than 25 per cent in excess of the conductor weight.

(See Table 22 of Appendix A for resultant loads on conductors.)

(*b*) Three districts have been outlined [3] in which heavy, medium, and light loading, respectively, are considered to be justified by weather reports as to wind and ice and by local experience of the utilities using overhead lines. A map of the United States showing the territory falling into each class of loading is given in Appendix A. This classification is the same as that for the calculation of transverse pressures on the supporting structures (rule 230) and is to be determined or modified as there indicated.

223. Recommended Normal Sags

(*a*) In grades of construction A, B, and C, conductors of hard, medium, and soft copper and aluminum shall have normal sags at 60° F as nearly as practicable to those given in Tables 12, 13, and 14 of Appendix A.[4] Greater or less sags may be used under the conditions outlined below.

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[3] Weather reports from 150 cities and towns in the United States relative to ice and wind will be given in a later Bureau publication.

[4] Additional tables will be given in a later Bureau publication.

(*b*) These sags are based upon experience and are designed to give the best results from the standpoint of safety and continuity of service. The sags are such that under normal conditions the tensions are substantially equal in the conductors of adjacent spans of different lengths not exceeding 150 feet. For the shorter spans the sags of different-sized conductors of the same span are substantially equal.

(*c*) The sags are such that the tensions in the medium and hard drawn copper conductors (under the assumed loading) are generally not in excess of one-half the breaking strength for grades A and B except for No. 6 and smaller. (See also rule 221.) For larger sizes in the shorter spans the tensions are considerably less than the above limiting value.

Less sags than those listed may be used if pins, fastenings, crossarms, and poles of sufficient strength to withstand the corresponding increase in longitudinal stresses are used, but no sag shall be so decreased from the tabulated values that, under the maximum assumed loading for the district, the tension will exceed 50 per cent of the breaking strength of the conductor concerned for grades A and B, and 60 per cent for grade C.

(*d*) In order to minimize danger from wires swinging together and to permit the moderate pin spacings and crossarm spacings sanctioned by modern good practice in overhead line construction, it is necessary to assign a limit to the sag, and hence to the recommended length of span of the smaller-sized wires, as indicated by the blank spaces in the tables. Longer spans may, however, be used with any conductor size if separations (see rules 241 and 242), clearances (see rules 240 and 243), and the sags given in Appendix A are correspondingly increased.

(*e*) Soft copper wire has a yield point less than one-half that of medium drawn copper, and hence stretches permanently with a correspondingly lighter loading of ice and wind. For this reason No. 6 soft copper should not be used in grades A and B construction except in light-loading districts, nor No. 4 soft copper in spans longer than 150 feet in grades A and B construction. It is recommended that medium hard drawn copper wire be used instead of soft in new construction, especially for sizes smaller than No. 2.

(*f*) Slack should be taken up when, because of the permanent elongation of the wire or movement of supporting structures, the sags listed have so increased that the clearances or separations of conductors are materially below the requirements of the rules.

In this connection it will be noted that the requirements for the vertical separation of conductors depend upon sag, and increase as the sag increases. As soft copper stretches much more than medium or hard, the taking up of slack will be necessary chiefly in lines where soft wire is used.

(*g*) Copper wire does not have so sharply defined a yield point as steel, but for practical purposes the yield point may be considered as that point beyond which the wire is permanently elongated and the sag permanently increased. If the wire when first strung is pulled to a tension approximately equal to half its breaking strength and then released and tied, its yield point is thereby raised and it will be less likely to stretch and its sag to increase under moderate loading of ice and wind.

Sec. 23. STRENGTH OF POLES, TOWERS, AND OTHER LINE SUPPORTS

230. Basis for Calculation of Transverse Loads Upon Poles and Towers

(*a*) In computing the stresses upon poles and towers for which grades of construction A, B, or C are required the assumed horizontal wind pressures at right angles to the direction of the line, upon the poles, towers, and conductors, shall be taken in regions of heavy loading for cylindrical surfaces, as 12 pounds per square foot of projected area for grade A, 7 pounds for grade B, and 4 pounds for grade C, the pressure being computed for the poles and towers without ice covering, while conductors are assumed to be covered with a layer of ice one-half inch in radial thickness.

Lightning protection wires and trolley contact conductors are included in computing transverse stresses. Certain signal conductors are exempted in computing transverse stresses. (See rule 286 *a*-5.)

(*b*) In regions of medium loading the transverse pressure shall be taken as two-thirds that for heavy loading districts and in regions of light loading the transverse pressure shall be assumed to be two-thirds that for medium loading districts, that is, four-ninths of that for heavy loading districts.

(*c*) A map of the United States showing the territory falling into each class of loading is given in Appendix A. (See also rule 222 *b*.) The localities in the different groups are classed according to the relative prevalence of high wind velocity and thickness of ice which accumulates on wires, light loading being for places where no ice of appreciable thickness ever accumulates on wire.

Where high-wind velocities are frequent in a given place the loading for that place may be classed as *heavy* even though ice does not accumulate to any greater extent than at some other place having less severe winds which has been classed as a *medium* loading district.

(*d*) In the absence of any action by the administrative authority fixing the loadings for any given jurisdiction the classification of loadings shown on the map in Appendix A shall be considered to apply unless the party or parties responsible for the lines concerned assume some modification of the same, based upon local experience or weather records, or both. These modifications shall be subject to review by the administrative authority.

231. Strength of Crossarms and Conductor Fastenings

(*a*) Cross arms for supply and signal lines, where grade A, B, or C construction is required for the crossarm, shall be of selected yellow pine or fir with the following minimum dimensions or, if other material, shall have at least equal strength: A and B, 2 or 4 pin, 3 by 4 inches; 6 or 8 pin, 3¼ by 4¼ inches. C, 2 or 4 pin, 2¾ by 3¾ inches; 6 or 8 pin, 3 by 4 inches.

(*b*) Crossarms for grades A, B, or C construction shall have sufficient strength (greater, when necessary, than that provided by the minimum dimensions given in (*a*) above) to withstand the service conditions, including transverse, vertical (see note 1 under rule 232 *a*) and unbalanced longitudinal stresses, to which they are exposed with a limit of unbalanced tension where conductor pulls are normally balanced, of 700 pounds at the outer pin.

(*c*) Pins, ties, and other conductor fastenings shall have sufficient strength to withstand the tension in the conductor, up to a limit of 700 pounds per pin or fastening.

Tie wires or fastenings shall have no sharp edges or burrs at contacts with the conductors.

(*d*) The height of the pin and of the conductor fastenings and the material and cross section of the pin should be so chosen as to afford the required strength. The method of attaching conductors by suitable ties to single, pin-type insulators mounted on 1.5 by 9 inch wood pins of locust or equivalent wood will usually provide strength up to 1000 pounds tension in the conductor with the conductor 3.5 inches above the crossarm.

Suitable steel pins afford greater strength both for the pins and for the crossarms.

(*e*) Crossarms shall be securely supported, by bracing if necessary, so as safely to withstand the vertical loads to which they may be subjected in use, including linemen working on them. In general, they should be maintained at right angles to the axis of pole and to the direction of the attached conductors, and at crossovers should be attached to that face of the structure away from the crossing, unless special bracing or double crossarms are used.

Double cross arms are generally used at crossings, unbalanced corners, and dead ends in order to permit conductor fastenings at two insulators, and so prevent slipping, although single crossarms might provide sufficient strength. To secure extra strength, double cross arms are frequently used, and crossarm guys are sometimes used.

232. Calculation of Loads upon Line Supports

(*a*) The loads upon poles, towers, and crossarms shall be taken as the following:

(1) VERTICAL.—Their own weight, plus the weight of the ice-covered conductors supported. The thickness of ice shall be taken as ½ inch in regions of heavy loading, ¼ inch in regions of medium loading, and no ice shall be considered in regions of light loading. (See Table 24 in Appendix B for vertical loads on conductors.)

(2) HORIZONTAL.—The assumed transverse pressures against their own surfaces (projected area when cylindrical) and against the ice-covered conductors, as specified in rule 230 above; heavy, medium, or light, according to the locality. (See Table 23 in Appendix B for transverse loads on conductors.)

(*b*) The calculated loads upon poles, towers, and cross arms shall be based upon the average span length where longer and shorter spans are interspersed except for spans which are over 25 per cent in excess of the average, in which case the actual span lengths shall be used.

In the case of crossings the actual length of span shall be used.

(*c*) In the calculation of all stresses no allowance shall be made for deformation, deflection, or displacement of any part of the supporting structures. (See also rule 220.)

(*d*) For flat surfaces the assumed unit pressure (see rule 230) shall be increased by 60 per cent. Where latticed structures are concerned, the actual exposed areas of one lateral face shall be increased by 50 per cent to allow for the pressure on the opposite face. If, however, this method of computing pressure on latticed structures indicates a greater total pressure than would occur on a solid structure of the same outside dimensions, the latter shall be taken as the limit.

233. Special Transverse Strength Requirements

(*a*) In the case of structures of grades A, B, or C construction where because of very heavy or numerous conductors or abnormally long spans the transverse strength requirements of this section can not be met except by the use of side guys or special structures, and it is physically impracticable to employ side guys, the transverse strength requirements may be met by side guying the line at each side of and as near as practicable to the crossing or other transversely weak structure, and with a distance between such side-guyed structures of not over 800 feet, provided:

(1) The side-guyed structures for each such section of 800 feet or less shall be constructed to withstand the calculated transverse load due to wind on the supports and ice-covered conductors, on the entire section between the side-guyed structures.

(2) The pole or tower structures so side guyed shall be rigid or head guyed away from the transversely weak section and have sufficient strength to withstand under the condition of loading prescribed in this section a load equivalent to the combined pull of all the conductors supported.

(3) The line between such side-guyed structures shall be substantially in a straight line and the average length of span between the side-guyed structures shall not be in excess of 150 feet.

(*b*) The cross arms, insulator pins, and conductor fastenings connected to the structures at each end of the transversely weak section shall be constructed to withstand, under the conditions of loading prescribed in rule 222, an unbalanced load equivalent to the combined pull in the direction of the transversely weak section of all the conductors supported up to 10 000 pounds, plus one-half the excess for grade A, or plus one-fourth the excess for grade B.

If the tension in any conductor does not exceed 1000 pounds, the necessary strength will usually be provided by the use of single wood pins and if the tension does not exceed 2000 pounds by the use of double wood pins provided the lever arm of the pin does not exceed 3.5 inches. (See Appendix A for tensions.)

(*c*) Except as modified in this rule the construction of the transversely weak section of the line shall be in accordance with the requirements for the grade of construction concerned. (See rules of section 22.)

234. Strength of Steel Poles and Towers and other Metal Supports

(*a*) Steel supports, steel towers, and metal poles, together with their foundations, and guys when used, shall be so designed and constructed as to withstand the stresses due to the loads assumed in rule 230 *a* above. Under those loads the calculated stresses in the steel members and in the guys shall not exceed the values given below in (*f*), which are intended to be limiting unit stresses, beyond which the structure as a whole would be liable to failure.

(*b*) The use of guys to obtain compliance with these requirements is regarded as generally undesirable. When guys are necessarily used, the steel supports or towers shall be regarded as taking all of the stress in the direction in which the guy acts, up to their safe working load, and the guys shall have sufficient strength to take the remainder of the assumed maximum stress, unless capable of considerable deflection. (See rule 251 *d.*)

(*c*) Steel towers, when carrying no conductors, shall have a minimum strength sufficient to withstand a transverse pressure double that designated for grade A construction.

(*d*) Steel towers or poles should preferably be placed on concrete or other suitable foundations extending above the ground line. If, however, the steel is set in earth, it shall be suitably protected against injurious corrosion at and below the ground line.

Since in many localities the soil and climatic conditions are such as to alter the strength of foundations considerably from time to time, there should usually be provided a considerable margin of strength in foundations above that which (by calculation) will just withstand the stresses under the assumption of average conditions of climate and soil.

(*e*) Unless sample structures are tested, or similar structures have been tested, to assure the compliance of structures in any line with these requirements, it is recommended that structures be designed to have a computed strength at least 10 per cent greater than that required by the rule.

(*f*) When steel supports or towers are used which are not capable of withstanding practically as great a stress longitudinally as transversely anchor towers shall be placed, at intervals not greater than 10 spans, which shall be able to withstand the combined longitudinal tension of all conductors up to 10 000 pounds plus one-half the excess above 10 000 pounds.

(*g*) The allowable unit stresses of steel shall be taken as follows:

Structural steel:	
Tension	27 000 pounds per square inch.
Shear	24 000 pounds per square inch.
Compression	$27\,000-90\,\frac{L}{r}$
Bolts, rivets, pins:	
Shear	24 000 pounds per square inch.
Bearing	48 000 pounds per square inch.
Bending	36 000 pounds per square inch.

These values are for structural steel having an ultimate tensile strength between 55 000 and 65 000 pounds per square inch and a yield point not less than 50 per cent of the ultimate strength.

(*h*) Steel poles or towers of grades A, B, and C shall have no less thickness of metal in members than the following:

Legs, galvanized, $\frac{3}{16}$-inch; other members, $\frac{1}{8}$-inch.

Legs, painted, $\frac{1}{4}$-inch; other members, $\frac{1}{4}$-inch.

Such steel poles or towers, including footings, shall be so constructed that all parts are accessible for inspection, cleaning, and painting, and that pockets are not formed in which water can collect. The ratio of L, the unsupported length of a compression member, to r, the least radius of gyration of the member, should generally not be greater than 150 for legs and 200 for other members having figured stresses.

The straight line formula for the allowable stress automatically limits the stresses in steel members to safe values even though the ratio L/r is greater than the values given above. In other words, for larger values of L/r, due to increasing L, the value of the stress is reduced so much that no hazard can result.

(*i*) Protective Covering or Treatment.—All iron or steel poles, towers, or supporting structures, and all hardware, including bolts, washers, guys, anchor rods, and similar parts of material subject to injurious corrosion under the prevailing conditions, shall be protected by galvanizing, painting, or other treatment, which will effectively retard corrosion.

235. Strength of Wood or Concrete Supports

(*a*) Wooden poles and crossarms and reinforced concrete poles and crossarms, together with their foundations and guys (when used) shall, when installed, be of such material and dimensions as will withstand the loads assumed in 230 *a* above, without the stresses under these loads exceeding 50 per cent of the assumed ultimate strengths of the materials. (For method of computing strength of construction, see Appendix B.[5]

(*b*) Wooden poles and crossarms should be replaced or reinforced when their strength has decreased to two-thirds that required by (*a*) above for new installations for grades A and B construction, and to one-half for grade C construction.

(*c*) With lines carried on wooden poles of not less than 8-inch top diameter, where a larger number of wires is required than permitted in (*a*) above, the initial pole and crossarm stress under the above loadings may be increased to 75 per cent of the assumed ultimate strength of the material as given in Appendix B, if the poles and crossarms are specially selected "clear" wood poles and are maintained by systematic inspection and treatment or repairs

[5] Additional information on this subject will appear in a later Bureau publication.

to not less than three-fourths of their required strength when new for all grades of construction.

(*d*) When guys are used to meet the strength requirements for wooden or concrete poles, they shall be considered as taking the entire stresses in the direction in which they act, the poles acting merely as struts.

(*e*) Wood poles in grades of constructions A, B, and C shall be of selected timber free from defects that would decrease their strength and durability and shall have no less nominal top diameters than the following:

Grade.	H. and M. loading.	L. loading.
	Inches.	*Inches.*
A	7	6
B and C	6	6

See Appendix B for data for computing transverse and longitudinal strength required for line supports and illustrative applications of the same.

Sec. 24. CLEARANCES AND SEPARATIONS OF LINE CONDUCTORS

Where supply and signal lines or supply lines of different voltage classifications are in conflict or on the same poles or towers the higher voltage lines shall, in general, be carried at the higher levels. (See rule 270 *b*).

240. Clearances of Conductors and Wires at Crossings

(*a*) CLEARANCES ABOVE RAILWAYS,[6] ROADWAYS, AND FOOTWAYS.—The clear space between the lowest overhead line conductors, guys, messengers, arc, or trolley span wires, or lightning protection wires and the heads of rails, crowns of streets, highways, alleys, or generally accessible spaces across or along (and above) which the former pass, shall not be less than given in Table 1, at 60° F with no wind, where the conductor or wire has fixed supports and the span does not exceed 150 feet.

[6] For wire crossings over "narrow gage" steam railways only, the clearances of Table 1 (see also rule 263) may be reduced by an amount equal to the difference between the height of "standard gauge" and "narrow gauge" box cars, but not less than values given in rule 275.

TABLE 1

Road Crossing Clearances

[The numbers represent the clearances in feet to be provided by the conductors or wires at the heads of columns, above places specified at the side of the table]

Nature of crossing	Signal, guys, spans, lightning-protection wires, supply lines less than 300 volts to ground, messengers	300 volts to ground up to 15 000 volts	15 000 to 50 000 volts[a]	Trolley contact wires (not feeder cables)
Crossing above track rails of railroads handling standard freight cars where brakemen are permitted on top	[b] 27	[b] 28	30	[c] 2
Crossing or along streets or alleys in urban districts or crossing streets or roads in rural districts (over the traveled way) or over track rails not included above	[d] 18	20	22	[e] 16
Along roads in rural districts	[d] 15	18	20	[e] 16
Crossings above spaces or ways accessible to pedestrians only	[f] 10	15	17	[e] 16

[a] For conductors exceeding 50 000 volts, the clearances given shall be increased at the rate of 0.5 inch or each 1000 volts excess.

[b] This clearance may be reduced to 25 feet when paralleled by trolley contact conductor on the same street or highway.

[c] In communities where 21 feet has been established, this clearance may be continued if carefully maintained. The elevation of the contact conductor should be the same in the crossing and next adjacent spans.

[d] This does not apply to guys which are not carried over, but merely beside, streets or alleys, unless also over driveways. Over roadways to residence garages, 10 feet is sufficient clearance.

[e] This clearance is the minimum clear height in the middle of the trolley contact conductor span, and the point of support at the trolley hanger should be at a height not less than 18 feet above the traveled way, thus allowing 2 feet for the total maximum sag at 60° F in span wire and trolley contact conductor.

[f] For guys, 8 feet will be sufficient and no clearance is required for anchor guys not passing across pathways, nor for those parallel with sidewalk curbs where traffic guards are provided.

(*b*) CONDUCTORS AND WIRES CROSSING OTHERS.—The clear space between the lowest overhead line conductor or wire and any other conductor or wire over which the former crosses (except for crossings between conductors and guy wires or span wires on the same poles, for which see rule 241) shall not be less than given in Table 2, at 60° F with no wind, where the upper conductor or wire has fixed supports and the sum of the distances from the point of intersection to the nearer supporting structure of each span does not exceed 100 feet.

Conductors of lines operating at the voltages indicated at the heads of columns should, in general, be installed above those to the left of the table, where a clearance is given in the usual type. The insertion of a given clearance in italics indicates that in general the lines operating at the voltage named above this clearance should not cross over the lines at the voltage to the left of the italicized clearance.

TABLE 2

Wire Crossing Clearances

Voltage classification	Signal	0 to 750 volts	750 to 7500 volts	7500 to 50 000 volts	Guys, messengers, span wires, lightning-protection wires, service loops [a]
Signal (including their cables and messenger)	2	[b] 4	4	6	2
0 to 750	4	2	2	4	2
750 to 7500	4	2	2	4	4
7500 to 50 000	6	4	4	4	6
Trolley-contact conductors	[c] 4	[c d] 4	6	6	4
Guys, messengers, span wires, lightning-protection wires, service loops [a]	2	2	4	4	2

[a] Guys, messengers, span wires, and lightning-protection wires may be either above or below the conductors by the clearances given. Service loops should not be above supply lines over 750 volts.

[b] A clearance of 2 feet may be permitted where the supply conductor is above the signal conductor, provided the crossing is not within 6 feet from any pole concerned in the crossing and the voltage to ground does not exceed 300 volts.

[c] Trolley-contact conductors above 750 volts should have at least 6 feet clearance. This clearance should also be provided over lower voltage trolley-contact conductors unless the crossover conductors are beyond reach of a trolley pole leaving the trolley-contact conductor or are suitably protected against damage from trolley poles leaving the trolley-contact conductor.

[d] Trolley feeders are exempt from this clearance requirement for trolley-contact conductors if they are at the same nominal potential and of the same system.

(*c*) Increased Clearances for (*a*) and (*b*).—(1) The clearances of (*a*) apply to spans not exceeding 150 feet. For longer spans they should be increased by 1 inch for each 10 feet excess between 150 and 300 feet and by 1 inch for each 20 feet of the excess beyond 300 feet.

(2) Where the sum of the distances from the nearest supporting structures of the two spans concerned to their point of intersection exceeds 100 feet, the clearances given under (*b*) shall be increased by 2 inches for each 10 feet of the excess between 100 and 200 feet and by 2 inches for each 20 feet of the excess beyond 200 feet.

(3) For voltages over 50 000 the clearances given in (*a*) and (*b*) shall be increased at the rate of 0.5 inch for each 1,000 volts excess.

(4) Where the upper line at a crossing between two lines is supported by suspension insulators, the clearances above lines crossed shall be increased sufficiently above those given in (*b*) to prevent the clearances from being reduced by the breaking of a conductor in either adjoining span by more than 25 per cent below the value given in (*b*).

The arrangement of insulators so that they are restrained from displacement toward the crossing will avoid the necessity of any increase over the given tabular clearances.

241. Minimum Values of Line-Conductor Clearances and Separations at the Supports (for any one Pole Line)

At any fixed support the clearances of line conductors from their supporting structures and attachments thereto (except insulators to which any conductor is attached), and the separation between any two line conductors, in construction of grades A, B, C, or D and for spans in which the apparent sag does not exceed 3 feet, shall be not less than the values given in the following table.

Cables, duplex, triplex, and twisted pair conductors, supported on insulators or messengers, whether single or grouped, are considered single conductors, even though they may contain individual conductors not of the same phase or polarity. Clearances between individual wires or cables supported by the same messenger or between any group and its supporting messenger are not subject to the provisions of this rule.

TABLE 3

Minimum Line-Conductor Clearances and Separations

[Applying to conductors of the same circuit or of different circuits. (See also rule 243 for lateral working space)]

Classification concerned	Horizontal separation between conductors not of the same phase or polarity	Clearance from span and guy wires attached to the same pole or from vertical or lateral conductors of other circuits	Clearance from surfaces of poles or cross arms or from vertical or lateral conductors of the same circuit
	Inches.	*Inches.*	*Inches.*
Signal	[a] 6	3	[b] 3
Direct-current railway feeders No. 4/0 or larger, 0–750 volts	6	[c] 6	3
Railway feeders 750–7500 volts and direct-current railway below No. 4/0, 0–750 volts	[d] 12	[c, e] 6	3
Supply conductors 0–7500 volts	[d] 12	[c, e] 6	3
For all conductors above 7500 volts add, for each kv. over 7500 volts	0.4	[e] 0.4	0.25

[a] The requirement does not apply at points of transposition of line conductors.

[b] Signal conductors may be attached to supports on the sides or bottoms of cross arms or on the surfaces of poles, if at least 4 feet from any supply line of less than 7500 volts and at least 6 feet from any supply lines of over 7500 volts carried on the same pole.

[c] Where a trolley feeder, supply line, or signal line is supported by the span wire concerned this clearance is not required.

[d] Where a separation of 10 to 12 inches has already been established by practice, for spans having apparent sags not over 3 feet (see Appendix A for apparent sags in level spans under different loading conditions and in different grades of construction) and for conductor voltage not over 7500, that minimum separation may be continued, subject to the provisions of rule 242. Where conductors, all of one material and either of one size or arranged with the smaller conductors below those of larger size, are supported on vertical racks in spans averaging not to exceed 150 feet, the minimum of Table 3 may be reduced to one-third the values given.

[e] Clearances from these conductors to guy, span, messenger, or lightning protection wires run in the direction of the line, shall be not less than the separation required between two line conductors of the voltage concerned.

242. Required Line-Conductor Clearances and Separations at the Supports

(*a*) FURTHER REQUIREMENTS FOR LINE-CONDUCTOR SEPARATIONS ACCORDING TO THE SAGS CONCERNED.—The separation, at the supports, of line conductors of the same or different circuits of grades A, B, C, D, or E, shall in no case be less than the values given by the following formulæ, in which S is the apparent sag, in feet, of the conductor having the greater sag if they are at the same level (the same crossarm):

Conductor separations in inches: For sizes below No. $2 = 0.2$ inch per kv. $+ 12\sqrt{S-2}$; for sizes No. 2 and larger $= 0.2$ inch per kv. $+ 7\sqrt{S}$.

The separation, at the supports, of line conductors at different levels (different crossarms) shall be determined by these same formulæ.

(*b*) FURTHER REQUIREMENTS FOR LINE-CONDUCTOR SEPARATIONS AND CLEARANCES AT THE SUPPORTS IF SUSPENSION INSULATORS ARE USED.—(1) Where suspension insulators are used and are not restrained from movement, the values of conductor separation required by Table 4 or by (*a*) shall be increased by one-half the length of the suspension insulator string.

(2) Where suspension insulators are used and are not restrained from movement, the conductor clearances from surfaces of supports, from span or guy wires, or from vertical or lateral conductors shall be such that the values of clearances required by Table 3 will be maintained with an insulator swing of 45° from the vertical position.

243. Lateral Working Space and Vertical Separation Between Conductors at Different Levels (on the Same Structure)

(*a*) The lateral working space between supply conductors and between supply and signal conductors, at different levels, shall have an approximate vertical height of not less than that given in Table 4, with a minimum of 2 feet.

(*b*) This space on the climbing side of the pole extends laterally from each side of the climbing space to the outer pin position of the arm and with a minimum horizontal width from the face of the crossarm equal to the width of the climbing space required for the highest voltage conductors concerned. (See rule 249 *a*.)

(*c*) No vertical or lateral conductors shall obstruct this working space. Such conductors, if not on the opposite side of the pole from the climbing side, must be at least as far from the crossarms as the width of the climbing space required for the highest voltage conductors concerned.

(*d*) Since buckarms obstruct the lateral working space between line conductors, not more than one single or double buckarm shall be placed on any pole, unless the voltage of all conductors concerned on the adjacent line crossarms above and below does not exceed 750, or unless the lateral working space required by the table is provided between the conductors attached to the buckarm and the conductors on the adjacent line arm to which the conductors on the buckarm are not connected.

This may be accomplished by increasing the spacing between the line crossarm gains.

(*e*) Exceptions.—The provisions of this rule do not apply to the vertical spacings between lines at different levels where men do not enter the spaces while the lines are alive. The vertical spacings given do not apply to conductors below 750 volts, where normal spans do not exceed 150 feet and conductors are carried on vertical racks at one side of the pole, if the full width of climbing space is maintained past the rack and at least 4 feet above and below, and the conductor separation is not less than permitted by Table 3 and its notes.

TABLE 4

Minimum Vertical Separations, in Feet, Between Line Conductors of the Same or Different Voltage Classifications When Carried on the Same Structures, but on Different Crossarms.

[In general, conductors of lines operating at the voltages indicated at the heads of columns are to be installed at levels above those at lower voltages to the left of the table when carried on the same structures, with the exceptions (f) to (l), below the table, and except that trolley-contact conductors and their associated feeders, which for convenience are carried at approximately the same level, are to be installed at levels below signal lines, at least 4 feet below signal lines for public use and at least 2 feet below signal lines not for public use. (For grades of construction of the higher lines see sec. 21.) The specified clearances usually indicate the minimum vertical separation between parallel crossarms (center to center) at the pole.]

Conductors at lower levels	Conductors at higher levels				
	0 to 750 volts	750 to 7500 volts (a)	7500 to 15 000 volts (a)	15 000 to 50 000 volts	15 000 to 50 000 volts (b)
Signal lines for public use	4 (c)	4	6	6	....
Signal lines not for public use	2	2	4	6	4
0 to 750	2	2	4	6	4
750 to 7500	....	2	4	6	4
7500 to 15 000	....	....	2	4	4

(*a*) Where lines are operated by different utilities a minimum vertical spacing between the respective conductor levels of 4 feet is recommended.

(*b*) Where lines are operated by one utility only, these reduced vertical separations may be used.

(*c*) In localities where the practice has been established of placing on commonly used poles crossarms carrying supply circuits of less than 300 volts to ground and cross arms carrying signal circuits for public use, at a vertical separation less than specified in the table, such existing construction (provided the minimum separation between the crossarms in question is not less than 2 feet) may be continued until the said poles are replaced; provided, however, that extensions to the existing construction shall conform to the clearance requirements specified in the table.

When signal lines are all in cable, a supply crossarm carrying only wires not exceeding 300 volts to ground may be placed at not less than 2 feet above the point of attachment of the cable to the pole; provided that the nearest supply wire on such cross arm shall be at least 30 inches horizontally from the center of the pole, and that the cable be placed so as not otherwise to obstruct the climbing space. (See rule 249 *i*.)

(*f*) Supply lines of any one voltage classification may be maintained on the same crossarm with supply lines of the next consecutive classification if they occupy pin positions on opposite sides of a pole; or if in bridge-arm construction they are separated by a distance of not less than the climbing space provided for in rule 249; or if the higher voltage conductors occupy the outer pin positions and the lower voltage conductors the inner pin positions; or vice versa, provided that in the latter arrangement the higher voltage conductors are those of series lighting or similar circuits which are ordinarily dead during periods of work on or above the crossarm concerned.

Where signal lines not for public use and supply lines below 750 volts are owned by the same utility, they may be placed on the same crossarm, when necessary.

(*g*) In localities where the practice of placing conductors of signal circuits for public use above supply conductors has been generally established, minor extensions with the conductors in the same relative positions and with the clearances covered by the table may be made in either system, but these extensions should not continue beyond a location at which it becomes practicable to change to the arrangement standardized by these rules.

(*h*) Where poles are used in common by separately owned utilities each of which may have supply conductors of different voltages on the same pole, supply conductors of a lower voltage of one utility may be placed at a higher level than those of a higher voltage of another utility in order to admit of keeping each utility's supply conductors in adjacent positions on the pole, provided that either (1) conductors of a lower voltage classification shall never be at a higher level than those of a higher classification, unless on the opposite side of the pole or (2) that a vertical spacing not less than 4 feet is maintained between the nearest line conductors of the respective utilitities, and this spacing be identified (if necessary) as a division space.

(*i*) Conductors of the same circuit arranged vertically on separate crossarms may occupy the same crossarms with conductors of other circuits of a different voltage similarly arranged, provided the clearance (rule 241) and climbing space (rule 249) specified for the higher voltage are maintained at each level concerned. When so arranged, the minimum vertical separation between crossarms shall be that required in Table 4 for the highest voltage concerned.

244. Conductors of Different Sags on the Same Supports

Line conductors at different levels and strung to different sags shall have vertical spacings at the supporting structures so adjusted that the minimum spacing at any point in the span, at 60° F with no wind, shall not be reduced more than 25 per cent from that provided for, by rules 241, 242, and 243, at the supports. Sags should be readjusted when necessary to accomplish the foregoing but not reduced sufficiently to conflict with the requirements of rule 223.

In cases where conductors of different sizes are strung to the same sag for the sake of appearance or to maintain unreduced clearances throughout storms, the chosen sag should be such as will keep the smallest conductor involved in compliance with the sag requirements of rule 223.

245. Clearances of Conductors of One Line from Poles and Conductors of Another Line

(*a*) Where conductors of one line are carried within 6 feet from a supporting structure of a second and conflicting line, and are not attached thereto, the conductors of the first line should be spaced at least as far from all surfaces of structures of the second line as required by rules 241 and 242 for separation between conductors of the circuit concerned. This minimum clearance shall be increased by 1 inch for each 2 feet distance between the supporting structure of the second line and the nearest supporting structure of the first line. In no case shall the climbing space on the structure of the second line be reduced by a conductor of the first line.

(*b*) The minimum clearance in any direction from any conductor of one line to any conductor of a second and conflicting line shall be 4 feet. In no case should the clearance be less than the values required by rules 241 and 242 for separation between similar conductors on the same support, increased (where approximately at the same level) by 1 inch for each 2 feet of the distance from the middle of the span of the first line to the middle of the span of the second line.

(*c*) Where conductors of one pole line cross over or under conductors of a second line there shall, if practicable, be not less than 3 feet clearance between the conductors of the first line and any pole or tower of the second line, unless the conductors are attached thereto. In no case should this clearance be less than the values required by rules 241 and 242 for separation between similar conductors on the same support, increased by 1 inch for each 2 feet of the distance from the supporting structure of the second line to the nearest supporting structure of the first line.

246. Clearances of Vertical and Lateral Conductors

(*a*) CLIMBING AND WORKING SPACES.—Vertical and lateral conductors, ground wires, and metal sheathed cables shall not obstruct the vertical climbing space (see rule 249), nor the lateral working space between line conductors at different levels (see rule 243), nor interfere with the safe use of pole steps, where such are installed.

(*b*) CLEARANCES FROM POLE CENTER.—Vertical conductors (except where especially protected, as per *d*, below) not exceeding 7500 volts shall clear pole centers by not less than 15 inches for a distance of not less than 4 feet above and below any open supply-line conductors which do not exceed 7500 volts when the latter are carried on or within 4 feet from the pole. If the vertical conductors exceed 7500 volts, this clearance shall be not less than 20 inches. If the supply-line conductors exceed 7500 volts, the clearance from pole center shall apply for a distance not less than 6 feet above and below.

(*c*) CLEARANCES BETWEEN CONDUCTORS AND FROM CONDUCTORS TO SURFACES AND STRUCTURES.—Vertical and lateral conductors, except where protected as per (*d*), below, shall have the following minimum separations and clearances from other conductors, pole surfaces, and guy, span, or messenger wires:

(1) From surfaces of supports and from other conductors of the same circuit . . . $3'' + 0.25''$ per kv. (highest voltage concerned) over 7500 volts.

Exception under rule 241 *b* applies. (See also *d* 2 below.)

(2) From span, guy, or messenger wires and from conductors of other circuits . . . $6'' + 0.4''$ per kv. (highest voltage concerned) over 7500 volts.

(3) From conductors on other supports as provided in rule 245.

The foregoing minimums are for situations where all conductors are rigidly supported on fixed supports. Where not so supported, greater separations and clearances shall be used. (See rule 242 *b*.)

(*d*) Specially Protected Conductors.—Vertical and lateral conductors may have less clearances than required by (*a*), (*b*), and (*c*) if they have suitable insulating coverings and are incased in conduit or other substantial casing (either of which is insulating, except on metal poles). On poles used only for supply lines the conduit may be omitted for conductors less than 7500 volts, and on poles used in common by supply and signal lines the conduit may be omitted for conductors below 300 volts to ground, if in lieu of conduit the following construction is used under the circumstances noted:

(1) Vertical and lateral supply conductors in connections to street lamps or underground circuits may be run on the street side of the pole in multiple conductor cable having suitable substantial insulating covering, if such cable is held taut at least 5 inches away from the surface of the pole and from any pole step, and as far away from the climbing space as practicable, and if the pole is stepped up to the lowest crossarm. Where within 8 feet from the ground a suitable mechanical protection shall be provided for all such conductors.

(2) Vertical and lateral signal conductors on poles carrying signal conductors alone or on poles used in common by signal and supply conductors may be attached directly to the surface of the pole structure by means of rings, knobs, or brackets, provided they are rubber-insulated twisted pair and do not obstruct the vertical climbing space nor reduce the clearances provided in rules 240 and 244 nor come within 4 feet from open supply lines of under 7500 volts nor within 6 feet from open supply lines of over 7500 volts, whether carried on the same or other supporting structures. Where within such distances, either the signal or supply conductors shall be incased in insulating conduit or in other substantial insulating and protective covering.

(*e*) Ground Wires and Grounded Metal-Sheathed Cables.—Vertical and lateral ground wires and grounded metal-sheathed cables, except where protected as noted below, shall have separations from other conductors and clearances from surfaces of supporting structures (unless metal) and from pole centers (unless crossarms are metal) not less than those required by rules 241 and 249 and by paragraphs (*a*), (*b*), (*c*), and (*d*), above, for conductors with which these wires or cables are associated.

(1) Where within the clearances named above they shall be inclosed in suitable insulating conduit wherever within 4 feet from any open supply lines of less than 7500 volts or within 6 feet from

such supply lines of over 7500 volts, whether carried on the same or other poles.

(2) In side-arm construction having only supply lines, and these carried on one side of the pole, the insulating conduit may, if necessary, be omitted, provided that the ground wires or metal-sheathed cables are placed on the opposite side of the pole from the line conductors and at least 5 inches away from pole steps located within 6 feet from any line conductor.

It is recommended that where practicable the ground wire or cable be insulated from wood poles by a nonabsorptive dielectric, either insulators or insulating tubing.

(*f*) Mechanical Protection for Ground Wires.—Where within 8 feet from the ground a suitable mechanical protective covering shall be provided over all ground wires and metal-sheathed cable, except in rural districts. Such protective covering, if for the only ground wire of a lightning arrester, shall be of insulating material.

(*g*) Conductors not in Conduit.—Conductors not incased in conduits shall have the same clearances from conduits as from other surfaces of structures.

(*h*) Where no Work is Done on Live Lines.—The provisions of *a*, *b*, *d*, and *e* of this rule do not apply to portions of a pole which workmen do not ascend while the conductors in question are alive.

247. Clearances from Buildings

(*a*) General.—Conductors should be so arranged and maintained as to hamper and endanger firemen as little as possible in the performance of their duties.

(*b*) Ladder Space.—Where buildings exceed three stories, or 50 feet, in height, overhead lines should be arranged where practicable so that a clear space (or zone) at least 6 feet wide will be left, either adjacent to the building or beginning not over 8 feet from the building, to facilitate the raising of ladders when necessary for fire fighting.

(*c*) Clearances, Low-Voltage Lines.—Supply conductors between 300 volts to ground and 7500 volts (unless in grounded conduit or metal-sheathed cable or otherwise adequately guarded or rendered inaccessible) shall be so arranged that they do not come nearer than 3 feet, measured horizontally, from any point on the surface of a building or its attachments nor nearer than 8 feet above the top of any building or above any balcony or other platform crossed over.

(*d*) Guards.—Where the above clearances can not be provided, or where supply conductors are placed near enough to windows, verandas, fire escapes, or other ordinarily accessible places to be exposed to contact of persons, the conductors shall be properly guarded by conduit, barriers, or otherwise.

(*e*) Where Attached to Buildings.—Where the permanent attachment of open supply conductors of any class to buildings is necessary for an entrance, conductors shall not be carried along or near the surface of the building unless they are guarded or made inaccessible where over 300 volts to ground and have separations from each other and clearances from building surfaces not less than those required by Table 3 (and its notes) for separation of conductors and clearances from pole surface.

(*f*) Clearance, High-Voltage Lines.—Conductors operating at over 7500 volts (unless in grounded conduit or metal-sheathed cable or otherwise adequately guarded or rendered inaccessible) shall be so arranged that they clear the surfaces of roofs or buildings or their attachments by not less than 8 feet up to 15 000 volts and 10 feet for higher voltages. They should not be carried over buildings not concerned in the operation of the utility owning them where this can be avoided.

248. Clearances from Bridges

(*a*) Accessible Portions.—Supply conductors (unless in grounded conduit or metal-sheathed cable) shall be so arranged that they do not come within 3 feet from any readily accessible wing wall or other readily accessible portion of any bridge or its attachments. For voltages higher than 7500 volts the minimum clearance shall be not less than required by paragraph (*b*).

(*b*) Ordinarily Inaccessible Portions.—Open supply conductors passing under, over, or near a bridge (other than brick, concrete, or masonry, requiring infrequent inspection or repair), when attached thereto, shall, when practicable, be so arranged that they do not come within the following distances from any portion of the bridge or abutments:

Operating voltage:	Clearance.
0 to 2 500	6. 0 inches.
2 500 to 5 000	1. 0 foot.
5 000 to 7 500	3. 0 feet.
7 500 to 15 000	5. 0 feet.
15 000 to 50 000	7. 5 feet.

(*c*) Where not Attached.—Open supply conductors passing over, under, or near a bridge (other than brick, concrete, or masonry, requiring infrequent inspection or repair), and not attached thereto shall be so arranged that they do not come within the following distances from any portion of the bridge or abutments:

Operating voltage:	Clearance, in feet.
Up to 7 500	3.0
7 500 to 15 000	5.0
15 000 to 25 000	7.5
25 000 to 35 000	9.0
Exceeding 35 000	12.0

The clearances as given above are minimums and should be increased as much as practicable.

(*d*) TROLLEY CONTACT CONDUCTORS.—Trolley contact conductors attached to the under surfaces of bridges shall be provided with a substantial inverted trough of nonconducting material, or other suitable means shall be taken to keep the trolley pole from making connection between the trolley contact conductor and the bridge structure.

(*e*) SEPARATIONS.—Where conductors attached to bridges are supported at frequent intervals, their separation may be less than that specified in rules 241 and 242, but not less than the following:

Span length:	Separation, in inches.
Up to 20 feet	6
20 to 50 feet	9

(*f*) WARNING SIGNS.—The pin-supporting structure attached to bridges shall be plainly marked with the name, initials, or trade-mark of the utility responsible for the attachment, and in addition, when the voltage of the conductors exceeds 750 volts. by the following or equivalent sign—"Danger—Do Not Touch."

249. Climbing Space

(*a*) SUPPLY LINES IN GENERAL.—All poles or structures carrying crossarms on which supply conductors above 300 volts to ground are carried shall be arranged and maintained so as to provide an unobstructed vertical climbing space between line conductors of not less than 30 inches horizontally each way and extending at least 4 feet above and below the conductors concerned. The climbing space need be on one side or corner only, of the pole structure. Where the supply conductors on a pole structure are all below 300 volts to ground, a climbing space of at least 24 inches shall be maintained.

(*b*) ABOVE 7500 VOLTS.—When men must climb between live conductors between 7500 and 15 000 volts, the climbing space should be increased to 36 inches where practicable.

(*c*) Signal Lines Below Supply Lines.—When signal conductors are carried on the same pole and below supply conductors, the same climbing space shall be provided through the signal conductors as is required for the supply conductors.

(*d*) Signal Lines Above Supply Lines.—When signal conductors are carried on the same pole and above supply conductors, the climbing space required for the supply conductors shall extend up to a point at least 48 inches above the highest supply conductors carried on the pole, and at least 6 feet above where the supply conductors exceed 7500 volts.

(*e*) Signal Lines Only.—It is recommended that poles carrying only signal lines, when these are above 150 volts to ground, shall be provided with a climbing space at least 24 inches horizontally each way.

(*f*) Where No Work is Done on Live Lines.—The rule is not intended to apply to lines above 15 000 volts, unless men climb between them while they are alive, in which case the proper dimensions of the climbing space will depend on the particular conditions. The rule is also not intended to apply to lines lower than 15 000 volts, if the unvarying practice and rules of the employers concerned prohibit employees from ascending beyond the conductors of the given line, unless the lines are killed or protected by suitable shields. In such cases a 24-inch climbing space is permissible.

(*g*) Protected Vertical Conductors.—Vertical runs incased in suitable conduit or other protective covering (see rule 246 *d*) and securely attached to the surface of the pole or structure, or the pole or structure itself when included in one side or corner of this space at buck or reverse-arm construction, are not considered to obstruct the climbing space.

(*h*) Protected Longitudinal Runs.—Longitudinal runs of cable or conductors are not considered to obstruct the climbing space if no supply line conductors carried on crossarms are within 4 feet, either above or below (see also exception in certain cases under note *c*, Table 4), if such cables or conductors are protected where within 20 inches from pole center by suitable guard arms securely fastened to the pole, or by substantial insulating conduit, unless located above supply line conductors or at least 6 feet below. If grounded metal-sheathed cables are uninsulated from metal supports attached to wood poles, similar protection shall be provided for such supports for at least 24 inches from the pole center.

(*i*) Special Clearance for Longitudinal Runs.—In cases where longitudinal runs of supply conductors not over 750 volts are supported near the surface of the pole, as by brackets or racks, or on pins close to the pole, unless they are located at levels at least 4 feet above or below other supply conductors carried on crossarms, sufficient side clearance from the pole center shall be provided for the line conductors on the adjacent crossarms to afford the full width climbing space for at least 4 feet above and below the longitudinal run concerned.

(*j*) Obstructions.—All poles should be kept free from posters, bills, tacks, nails, and other unnecessary obstructions, such as through bolts not properly trimmed.

Sec. 25. SUPPORTING STRUCTURES AND ATTACHMENTS

250. Poles and Towers

(*a*) Poles, towers, and other supporting structures shall be so located, when practicable, as to provide horizontal clearances from them to the nearest point of hydrants and signal pedestals of not less than 4 feet and to curb lines (unless poles are suitably protected from traffic) of not less than 6 inches.

(*b*) Where hydrants are located at street corners, poles should not be set so far from them or from the corners as to make necessary the use of flying taps inaccessible from the poles. (See rules 205 *d* and 255 *a*.)

(*c*) Where necessary, poles exposed to excessive abrasion by traffic shall be protected by guards.

(*d*) Poles shall be so placed, guarded, and maintained as to be exposed as little as practicable to brush, grass, rubbish, or building fires.

251. Guys and Anchors

(*a*) When the mechanical loads to be imposed on poles, towers or other supporting structures are greater than can be safely supported by the poles or towers alone, additional strength shall be provided by the use of guys, braces or other suitable construction.

(*b*) Where it is physically impracticable to employ side guys or special structures, and the necessary strength can not be secured for any pole without side guying, the necessity for side guys may be met (except for construction of grade A, B, or C, for which see rule 233) by head and side guying the line at adjacent or nearby poles not farther than 500 feet from the given pole; provided the line is straight between the guyed poles, with spans not exceeding 150 feet, and the guyed poles are capable of withstanding the loading for which they are designed, on the assumption that the whole transverse stress of the line between the guyed poles is carried by them.

(*c*) Guys should also, when necessary, be used wherever conductor stresses are not balanced, as at corners, angles, and dead ends, to prevent undue increase of sags in adjacent spans as well as to provide sufficient strength for those supports on which the stresses are constantly unbalanced.

(*d*) When guys are used with wood poles or other poles or towers capable of considerable deflection before failure they shall be able to support the entire stress in the direction in which they act, the pole acting simply as a strut.

(*e*) The guy should be attached to the structure as near as practicable to the center of the conductor load to be sustained.

(*f*) Guy wires should be stranded and where attached to anchor rods should be protected by suitable guy thimbles. Cedar and other soft-wood poles to which any guy having a strength of 10 000 pounds or more is attached, should be protected by the use of suitable guy shims, and in this case guy hooks or other suitable means should be provided to prevent the guys from slipping along the poles. Guy hooks should also be used wherever the horizontal distance from anchor to pole is less than two-thirds the vertical height of the guy attachment to the pole above the anchor.

(*g*) Guys attached to metal poles or structures should be insulated from them by suitable blocking, when liable to be subject to electrolysis of the anchors, unless insulators are placed in the guys themselves.

(*h*) Anchor rods shall be so installed as to be in line with the pull of the attached guy when under load, except in rock or concrete.

252. Insulating or Mechanical Guards for Guy and Span Wires

(*a*) Except as noted below, each guy wire or guy cable attached to any pole or structure carrying supply conductors of above 300 volts to ground, and not exceeding 15 000 volts, shall be equipped with an effective insulator located not less than 8 feet above the ground, and at such a point that if the guy wire breaks at or below the insulator, the part above the insulator can not be reached from the ground.

(*b*) When the guy wire to any pole, carrying supply, or signal conductors, or both, is carried above overhead supply conductors of above 300 volts to ground, two or more insulators shall, where hazard would otherwise exist, be used so that so far as possible the exposed section of the guy wire shall be between two insulators. Neither insulator shall be within 8 feet from the ground and the insulators shall be so located that in case of sagging or parting of the guy, no part in contact with the live line on the same or another pole can come within 8 feet from the ground.

(*c*) The anchored end of the guy wires attached to wood poles carrying lines of above 15 000 volts shall, except in rural districts, be permanently grounded (see sec. 9) wherever this part of the guy has a clearance of less than 8 feet to ground, unless an insulator is used which is permanently effective against the highest voltage which is liable to be impressed across it.

(*d*) Where guys in which it is necessary to install insulators are so arranged that one crosses or is above the other, insulators shall be so placed that in case any guy sags down upon other guys the insulators of neither are liable to become ineffective.

(*e*) Guy insulators shall have a mechanical strength at least equal to that of the guys in which they are installed.

(*f*) Exceptions.—The placing of an insulator in a guy wire or guy cable will not be required where the guy wire or guy cable is electrically connected to grounded steel structures or to a ground connection on wooden poles.

Where guys are uniformly permanently grounded (see sec. 9) throughout any system of overhead lines, strain insulators will not be required.

(*g*) All span wires, including bracket span wires, shall have a suitable insulator (in addition to an insulated hanger if used) inserted between each point of support of the span wire and the lamp or trolley contact conductor supported, except that single insulation may be permitted when the span wire or bracket is supported on wooden poles supporting no other conductor than those operated by the utility controlling the span wire or bracket. This rule does not apply to insulated feeder taps used also as span wires.

(*h*) Effective insulators should be inserted at least 8 feet from the ground in metallic suspension ropes or chains supporting lighting units of series circuits.

(*i*) The ground end of all guy wires or cables attached to ground anchors exposed to traffic shall be provided with a substantial and conspicuous wood or metal guard not less than 8 feet long.

It is recommended that in exposed or poorly lighted locations such guards be painted white or some other conspicuous color.

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253. Transformers, Regulators, Lightning Arresters, Switches, and Similar Equipment on Supply Lines

(*a*) Transformers, regulators, lightning arresters, and switches when located below conductors or other attachments shall be maintained, where practicable, on that side of the pole opposite to the climbing side, at that point.

On buckarm poles the climbing space and the lateral working spaces parallel to either the line arms or the branch arms shall be kept clear, if practicable.

(*b*) When conductors are located above them, current-carrying parts of switches, automatic cut-outs, and lightning arresters, if exceeding 300 volts to ground, and located on the climbing side of the pole, shall be inclosed or suitably guarded, if less than 20 inches from the pole center, except when located on or above the top crossarm.

(*c*) All current-carrying parts of switches, automatic cut-outs, lightning arresters, also transformer connections and other connections which may require operation or adjustment while alive and are exposed at such times, shall be so arranged that in their adjustment while alive the hand need not be brought nearer to any other current-carrying part at a different voltage than the clearances from pole surfaces required in Table 3 for conductors of corresponding voltages. (See also rules 440, 441, and 442.)

254. Insulators

(*a*) Insulators for operation on supply lines of grades A and B construction at voltages exceeding 7500 shall be of porcelain or other material which will give equally good results in respect to mechanical and electrical performance and durability and shall be marked by the makers with a classification number and maker's name or trade-mark, the marks being so applied as not to reduce the electrical or mechanical strength of the insulator.

(*b*) Wherever grounded metal pins or grounded crossarms or metal towers are used at a cross-over span support of grade A or B construction, with wood pins or crossarms or poles used within five spans of the crossing, the insulators used on such grounded or metal supports shall be capable of withstanding a voltage 50 per cent higher than those in other portions of the line. Where strain insulators are used, they shall be capable of withstanding, under their normal mechanical stress, at least as high a voltage as the line insulators in general, or shall be capable, when not under mechanical stress, of withstanding a voltage 25 per cent greater.

(*c*) Insulators in grades A and B construction should be so designed that their dry flash-over voltage is not more than 75 per cent of their puncture voltage at a frequency of 60 cycles.

(*d*) Insulators to which are attached conductors in grades A or B construction shall be capable of withstanding without flash over at the frequency of 60 cycles the voltages shown in the following table:

TABLE 5

Voltage of circuit	Flash-over voltage	
	Dry	Wet
750	5000	3500
2300	11 000	8000
4000	17 000	13 000
6600	27 000	20 000
7500	30 000	22 000
11 000	40 000	30 000
22 000	75 000	55 000
33 000	105 000	75 000
44 000	135 000	95 000
55 000	160 000	115 000
66 000	185 000	135 000
88 000	235 000	170 000
110 000	285 000	200 000
150 000	375 000	225 000
200 000	490 000	250 000

By the term "wet" is meant a condition equivalent to a precipitation of one-fifth inch of rain per minute at an angle of 45 degrees to the axis of the insulator.

(*e*) Each completed pin-type insulator for line voltages over 15 000 where used in construction of grades A or B, and each completed suspension insulator disk, shall be subjected to a routine factory test at dry flashover voltage at a frequency of 60 cycles or any other test which may be generally sanctioned by good modern practice.

(*f*) In installing the insulators and conductors of grades A and B construction precautions shall be taken to guard against the possibility of arcs or leakage current injuring conductors or burning any wooden parts of the supporting structure which would render the conductors liable to fall.

255. Branch Connections

(*a*) Connections of branches in supply circuits, service loops, and equipment in overhead construction shall be readily accessible to authorized employees and when possible at poles or other structures. (See rules 205 *d* and 250 *b*.)

(*b*) Such connections shall be so supported and spaced that swinging or sagging can not bring them in contact with other conductors nor interfere with the safe use of pole steps nor reduce the climbing or lateral working space. (See rule 246.)

256. Lamps

(*a*) All exposed metal parts of lamps and all such parts of their supports unless effectively insulated (see rule 254) from the parts carrying current shall be maintained not less than 20 inches from surfaces of pole structures if of wood (unless at pole tops) and maintained at a suitable height above roadways and footways.

When lamps are maintained on the side of the pole structure opposite that designated as the climbing side this clearance may be reduced to 5 inches.

(*b*) The lowering rope or chain for lighting units arranged to be lowered for examination or maintenance shall be of a material and strength designed to withstand climatic conditions and to safely sustain the lighting unit. The lowering rope or chain, its supports, and fastenings shall be examined periodically.

(*c*) A suitable device shall be provided by which each lighting unit on series circuits over 300 volts to ground may be safely and entirely disconnected from the circuit before the lamp is handled unless the lamps are always worked on from suitable insulating stools, platforms, or tower wagons and treated as under full voltage of the circuit concerned. Exempted from this provision are lamps, such as incandescent lamps, which in themselves present a noncurrent-carrying surface which may be utilized as a handle to safely remove them from the circuit.

257. Tree Trimming

Where trees exist near supply-line conductors, they shall, if practicable, be so trimmed that neither the movement of the trees in wind or ice storms nor the swinging or increased sagging of conductors in wind or ice storms or at high temperatures shall bring about contact between the conductors and the trees; except that for the lower-voltage conductors, where trimming is difficult, the conductor may be protected against grounding through the tree and against abrasion by interposing between it and the tree a sufficiently nonabsorptive and substantial insulating tubing or strip.

Sec. 26. CROSSING OF SUPPLY LINES WITH RAILWAYS AND WITH SIGNAL LINES

A. UNDERGROUND AND UNDERBRIDGE CROSSINGS OF SUPPLY LINES BENEATH RAILWAYS

260. Compliance with Rules of Other Sections

(*a*) Underground supply lines crossing railways shall conform to the requirements of sections 20 and 29, and particularly of rules 290 and 295. Manholes, pull boxes, and terminals shall, where practicable, be located outside the fenced right of way of any railway. Conductors and cables carried underground, under railways, shall be placed in suitable ducts conforming to the requirements of section 29.

(*b*) Overhead supply lines passing beneath bridges over which railways pass shall conform to the requirements of sections 20, 21, 24, and 25, and particularly of rule 248. Where such lines also cross or conflict with or occupy common poles with other lines they shall also comply with all the requirements of sections 26, 27, and 28, which apply to these conditions.

Supply lines using wood pins and crossarms and supports generally of nongrounded construction within five spans of the point of attachment shall, at points of their attachment to steel bridges, have insulators capable of withstanding a voltage 50 per cent higher than those in other portions of the line. Strain insulators used at such points shall be capable of withstanding, under their normal mechanical stress, at least as high a voltage as the line insulators in general, or shall be capable when not under mechanical stress of withstanding a voltage 25 per cent higher.

B. OVERHEAD CROSSINGS OF SUPPLY LINES OVER RAILWAYS

261. Compliance with Rules of Other Sections

(*a*) Grade of Construction.—Overhead supply lines (or signal lines which have taken on the character of supply lines, see rule 210) crossing over railways shall have grade A construction, except when over only sidings, spurs, branches, or other unimportant railways, in which case they should have grade B construction. (See rules 211 and 212 for full statement.)

(*b*) Conductor Stringing, Supports, Insulators.—Such overhead supply lines shall conform as to conductor sizes, materials, and sags, with the requirements of section 22; as to materials, sizes, and strength of supporting structures and attachments, with the requirements of section 23; as to separations and clearances of conductors and wires on the supply itself, with the requirements of section 24; as to guys and their insulators, with the requirements of section 25; as to the electrical properties of insulators, with rule 254; and in general with the requirements of sections 20 and 21.

(*c*) Where Concerned with Other Lines.—Such overhead supply lines, where also concerned at the crossover with other lines of any kind, by way of either crossing, conflicts, or common use of poles with other lines, shall conform to the requirements of rules 210 as to relative level and with 214 to 219 as to the character of mechanical construction, and with the rules of sections 26, 27, and 28, which apply to these conditions, in addition to the requirements of this rule.

262. Pole Clearance to Rail

Poles or towers supporting the crossover spans of overhead supply lines over railways shall, unless physical conditions or municipal requirements prevent, have side clearance not less than 12 feet from the nearest track rail, except that at sidings a clearance not less than 7 feet may be allowed. At loading sidings sufficient space shall be left for a driveway.

If overhead lines of the railway are crossed over, the pole or tower structures of each line concerned in the crossover shall have clearances from the conductors of the other line (unless attached) as required by rule 245 *c*.

263. Wire Clearance above Rail

The clear space between the lowest overhead supply line conductor or overhead ground wires and the heads of rails above which the former cross shall not be less than the following at 60° F with no wind, where the conductor or wire has fixed supports and the span does not exceed 150 feet.

(*a*) Above track rails of railways handling standard freight cars where brakemen are permitted on top:

(1) Supply lines of less than 300 volts to ground, overhead ground wires, and their guy, messenger, and span wires, 27 feet.

This may be reduced to 25 feet where lines are paralleled by trolley contact conductors on same street or highway.

(2) Supply lines, 300 volts to ground up to 15 000 volts, 28 feet.

This may be reduced to 25 feet where lines are paralleled by trolley contact conductors on same street or highway.

(3) Supply lines, 15 000 to 50 000 volts, 30 feet.

For conductors above 50 000 volts the given clearance shall be increased at the rate of 0.5 inch per 1000 volts excess.

(4) Trolley contact conductors, 22 feet.

In communities where 21 feet has been established this clearance may be continued if carefully maintained. The elevation of the contact conductor should be the same in the crossing and next adjacent spans.

(*b*) Above track rails of electric and other railways where brakemen are not permitted on top of cars, the clearances shall be at least 18, 20, 22, and 16 feet, respectively, in the four cases given above.

The given trolley clearance (16 feet) is the minimum clear height in the middle of the trolley contact conductor span, and the point of support at the pole structure should be at a height of not less than 18 feet above the track rail, thus allowing 2 feet for the total maximum sag at 60° F. in span wire and trolley contact conductor.

(*c*) Increased Clearance for (*a*) and (*b*).—The clearances of (*a*) and (*b*) apply to spans not exceeding 150 feet. For longer spans they should be increased by 1 inch for each 10 feet excess between 150 and 300 feet and by 1 inch for each 20 feet of the excess beyond 300 feet.

264. Crossover Wire Clearances to Railway Wires

The clear space between the lowest overhead supply line conductor or guy or span wire crossing over any conductor or wire concerned in the operation of the railway (except for crossings between conductors and guy or span wires on the same poles, for which see rule 241) shall not be less than given below, at 60° F, with no wind or other mechanical loading of the conductors or wires, where the upper conductor or wire has fixed supports (pin or strain-type insulators), and the sum of the distances from the point of intersection to the nearest supporting structure of each span, does not exceed 100 feet.

(*a*) Above signal conductors (of railways):

	Feet.
Supply lines 0 to 750 volts	4
This may be reduced to 2 feet if the crossing is not within 6 feet of any pole concerned in the crossing and the voltage is not over 300 volts.	
Supply lines, 750 to 7500 volts	4
Supply lines, 7500 to 50 000 volts	6
Service supply connections	2
Guy, messenger, and span wires	2

(*b*) Above supply conductors (over 400 volts to ground and supplying railway signal systems):

	Feet.
Supply lines, 0 to 750 volts	2
Supply lines, 750 to 7500 volts	2
Supply lines, 7500 to 50 000 volts	4
Guy, messenger, and span wires	4

(*c*) For clearances above trolley contact conductors, see section 27.

(*d*) Above guys, messenger, and span wires (of railways):

	Feet.
Supply conductors, 0 to 750 volts	2
Supply conductors, 750 to 50 000 volts	4
Guy, messenger, and span wires of supply lines	2

Guys, span wires, and messenger wires may be either above or below the conductors by the given clearances.

265. Increase of Clearances in Special Cases

(*a*) Clearance Increase for Long Spans.—The clearances of rule 264 shall be increased where the sum of the distances from the point of intersection to the nearest supporting structure of each span exceeds 100 feet by 2 inches for each 10 feet of the excess between 100 and 200 feet, and by 2 inches for each 20 feet of the excess beyond 200 feet.

(*b*) Clearance Increase for High Voltage.—The clearances of rule 264 shall be increased, where the supply line voltage exceeds 50 000 volts, by 0.5 inch per 1000 volts excess.

(*c*) Clearance Increase for Suspension Insulators.—The initial clearances, where the upper line at a grade A or B crossing over track rails or signal lines is supported by suspension insulators, shall be sufficient to prevent the minimum clearances of rules 263 and 264 from being reduced through the breaking of a conductor in either adjoining span by more than 10 per cent over rails or by more than 25 per cent over conductors or wires.

The arrangement of insulators so that they are restrained from displacement toward the crossing will obviate necessity of any increase over the clearances given in rules 263 and 264.

266. Special Longitudinal Strength Requirements for Crossing Sections of Grades A and B Construction in Lines of a Lower Grade of Construction (or Adjacent to Angles or Dead Ends)

(*a*) Required Strength.—The supporting structures (including poles, towers, crossarms, insulator pins, and conductor fastenings) for the ends of the crossing section of the line shall be constructed to withstand under the conditions of loading prescribed in rule 222 a longitudinal stress equivalent (except as noted in *d*) to the combined pull in the direction of the crossing of all the conductors and lightning protection wires supported, the pull of each conductor being taken as the tension in the conductor due to the prescribed loading. (See rule 231 for strength of crossarms and pins.) Where it is difficult to increase the longitudinal strength, the longitudinal stresses shall be reduced by increasing the conductor sags (and if necessary the conductor separations).

(*b*) Flexible Supports.—When crossover supports are capable of considerable deflection in the direction of the line, as with wood or concrete poles, or some types of metal poles and towers, it may be necessary to increase the normal clearances specified in rule 263 above, or to provide head guys or special reinforcement to prevent such deflection. So-called flexible steel towers or frames shall not be used at such locations.

(*c*) Methods for Obtaining Required Strength—The requirements of (*a*) can be met by one of the following methods:

(1) By the use of sufficiently self-supporting or head-guyed structures capable of withstanding the longitudinal stress at either side of the crossing span.

(2) By the use of sufficiently self-supporting or head-guyed structures, capable of withstanding the longitudinal stress, located at one or more span lengths away from the crossing, within a distance of 500 feet on either side and with not more than 800 feet between the longitudinally strong structures, provided such structures and the line between them and the crossing meet the requirements as to transverse strength and stringing of conductors which apply to the crossing span, and provided that the line between the guyed end structures is approximately straight or suitably side guyed.

(3) By distributing the longitudinal stress over two or more structures on either side of the crossing, special strength being given to the end structures when necessary and all such structures and the line between them and the crossing complying with the requirements of section 23 as to transverse strength and conductor stringing.

(*d*) Modified Strength Requirement for Heavy Lines.—In cases where the line is approximately straight on both sides of the crossing span and in line with the crossing, the construction shall be such as to withstand the combined stress in the conductors at the crossing up to 10 000 pounds combined pull, plus one-half the excess above 10 000 pounds for grade A, and plus one-fourth the excess for grade B, if the line on one or both sides of the crossing or special construction should fail in whole or in part. In cases where, due to change of direction of the line or because of dead ends the longitudinal stresses in the crossing conductors are not even normally balanced by the conductors of the line beyond the crossing construction, the construction shall be such as to withstand the total combined stress.

Where the poles or towers supporting the crossing section are not in line with the line beyond the crossing section, suitable guys shall be placed to withstand the resulting transverse stresses.

267. Protection Against Conductor Breakage

(*a*) Splices and Taps.—Splices shall not be made in the crossing span and preferably not in the adjacent spans, which are depended upon for withstanding the longitudinal stress of the crossing conductors. If a splice or tap is made in any conductor in the span next to the crossover span, it shall, where practicable, be placed at a point nearer to the crossover support than is the nearest conductor crossed over.

It is not the intent of this rule to prohibit the installation, in either the crossing or adjacent spans, of reliable protective devices of the drop-out disconnector type that require making a joint in the conductor.

(*b*) Falling Trees.—The crossing span and the next adjoining spans, so far as practicable, shall be kept free from overhanging or decayed trees, which might fall into the line. (See also rules 250 and 257.)

(C) OVERHEAD CROSSINGS OF SUPPLY LINES OVER SIGNAL LINES

268. Special Requirements and Compliance with Rules of Other Sections

(*a*) Grade of Construction.—Overhead supply lines (or constant-current circuits (see rule 278) or signal lines which have taken on the character of supply lines, see rule 210), crossing over signal lines under the circumstances noted in rule 214 *a* and *b*, in rule 215 *a* and *b*, and in rule 216 *a* and *b*, shall have grades of construction A, B, or C, as noted in the rules referred to. Where the signal lines crossed over are not for public use, the requirement that the crossover supply line span conform to one of the above grades may be waived under the conditions stated in rule 210.

(*b*) Conductor Stringing, Supports, Insulators.—Such overhead supply lines shall conform as to conductor sizes, materials, and sags with the requirements of section 22; as to materials, sizes, and strength of supporting structures and attachments with section 23; as to separations and clearances of conductors and wires of the supply line itself with the requirements of section 24; as to guys and their insulators with the requirements of section 25; as to the electrical properties of insulators with rule 254, and in general with the requirements of sections 20 and 21.

(*c*) Where Concerned with other Overhead Lines or with Railways.—Such overhead supply lines, where also concerned at the crossover with crossings, conflicts or common use of poles with other overhead lines than the signal lines crossed over or with a railway crossing, shall conform also to the requirements of rules 210 as to relative level and with 211 to 219 as to character of construction, and with the rules of sections 27 and 28 and of other rules of this section which apply to these conditions.

(*d*) Pole Clearance.—The pole or tower structures of each line concerned in the crossover shall have clearances from the conductors of the other line (unless attached), as required by rule 245 *a* and *c*.

(*e*) Wire Clearance above Signal Wires.—The clear space between the lowest overhead supply line conductor or guy, messenger, or span wire, crossing over any signal line conductor or guy, span, or messenger wire (except for crossings between conductors and guy, messenger, or span wires on the same pole, for which see rule 241), shall not be less than given below, at 60° F, with no wind or other mechanical loading of the conductors or wires, where the upper conductor or wire has fixed supports (pin or strain-type insulators), and the sum of the distances from the point of intersection to the nearest supporting structure of each span does not exceed 100 feet.

(1) Above signal conductors:

	Feet.
Supply lines, 0 to 750 volts	4
This may be reduced to 2 feet, if the crossing is not within 6 feet from any pole concerned in the crossing, and the voltage is not over 300 volts.	
Supply lines, 750 to 7500 volts	4
Supply lines, 7500 to 50 000 volts	6
Service supply conductors	2
Guy, messenger, and span wires	2

(2) Above guy, span, or messenger wires (of signal lines):

	Feet.
Supply lines, 0 to 750 volts	2
Supply lines, 750 to 50 000 volts	4
Guys, messengers, and span wires	2

Guys, span wires, and messenger wires may be either above or below the conductors by the given clearances.

(*f*) Clearance Increase for Long Spans.—The clearances of (*e*) shall be increased where the sum of the distances from the point of intersection to the nearest supporting structure of each span exceeds 100 feet, by 2 inches for each 10 feet of the excess between 100 and 200 feet, and by 2 inches for each 20 feet of the excess beyond 200 feet.

(*g*) Clearance Increase for High Voltage.—The clearances of (*e*) shall be increased, where the supply line voltage exceeds 50 000 volts, by 0.5 inch per 1 000 volts excess.

(*h*) Clearance Increase for Suspension Insulators.—The initial clearances, where the upper line at a grade A or B crossing over signal lines is supported by suspension insulators, shall be sufficient to prevent the minimum clearances of (*e*) from being reduced through the breaking of a conductor in either adjoining span, by more than 25 per cent.

The arrangement of insulators so that they are restrained from displacement toward the crossing will obviate the necessity for any increase over the clearances given in (*e*).

(*i*) Special Requirements for Crossing Sections of Grades A and B Construction in Lines of a Lower Grade of Construction.—For special requirements for longitudinal strength of crossover supports of supply lines crossing over signal lines, where grades A or B are required, see rule 266.

(*j*) Splices and Taps.—Splices shall not be made in the crossing span, and preferably not in the adjacent spans which are depended upon for withstanding the longitudinal stress of the crossing conductors. If a splice or tap is made in any conductor in the span next to the crossover span, it shall, where practicable, be placed at a point nearer to the crossover support than is the nearest conductor crossed over.

It is not the intent of this rule to prohibit the installation, in either the crossing or adjacent spans, of reliable protective devices, of the drop-out disconnector type that require making a joint in the conductor.

(*k*) Falling Trees.—The crossing span and the next adjoining spans, so far as practicable, shall be kept free from overhanging or decayed trees, which might fall into the line (see also rules 250 and 257).

269. Special Short Span Crossing Construction

In cases where the crossover span is constructed of such a height that its length is less than the distance between either point of support of its lowest conductor and the highest conductor of the line crossed, the requirements for conductor sags and for size and type of conductors in section 22 are waived, provided that a permanently grounded guard arm is installed at each crossover support in such a manner as to prevent conductors, which break in either adjacent span, from swinging back into the conductors of the span crossed over.

This character of construction is facilitated where the span crossed over is at a minimum elevation above ground level, and where the crossover supports can be placed quite near together.

Sec. 27. OVERHEAD SUPPLY LINES (OR SIGNAL LINES WHICH HAVE TAKEN ON THE CHARACTER OF SUPPLY LINES) IN VARIOUS SITUATIONS

270. Separation of Pole Lines to Avoid Conflict

(*a*) Arrangement in General.—Two parallel pole lines, either of which carries supply lines, shall, where practicable, be so separated from each other that neither conflicts with the other (see definition 41). If this can not be done, the two pole lines shall be separated as far as practicable. (See also rule 245.)

It is recommended that overhead lines which can not readily be so separated from each other as not to conflict be placed on a single common pole line unless the high voltage of certain of the circuits, or the large number of conductors, makes the use of a single pole line undesirable or impracticable.

(*b*) Standardized Levels.—It is recommended that, where practicable, lines be arranged, by mutual agreement of the utilities concerned, at standardized levels throughout a given community, in order to minimize difficulties when new crossings or extensions to existing lines are to be installed. (See also rule 240 *b*, second paragraph, for relative levels.)

(*c*) Pole Clearance.—Poles, towers, and other supporting structures shall be so located, when practicable, as to provide horizontal clearances from them to the nearest point of hydrants and signal pedestals of not less than 4 feet, and to curb lines (unless poles are suitably protected from traffic) of not less than 6 inches.

Where hydrants are located at street corners poles should not be set so far from them or from the corners as to make necessary the use of flying taps inaccessible from the pole. (See rules 205 *d* and 255.)

Where railway tracks are paralleled by overhead lines, the poles shall be located if practicable not less than 12 feet from the nearest track rail.

Supports for overhead trolley contact conductors may be located as near their own track rail as conditions require. If very close, however, permanent screens on cars will be necessary to protect passengers.

271. Supply Lines in Urban Districts; Compliance with Other Rules

(*a*) BELOW 750 VOLTS.—Supply lines below 750 volts, in urban districts, where alone, or crossing above signal lines, or crossing above other supply lines below 750 volts, or where conflicting with such signal or supply lines, or where on common poles with such signal or supply lines, are subject to no special rules (no grade of construction) for conductor stringing or strength of supports, but shall comply with the general rules of sections 20, 24, and 25, as to isolation, guarding, clearance, and pole arrangement.

For clearances of such lines from streets, roadways, and conductors or wires crossed see rule 275 below.

For situations where such lines are carried over overhead trolley contact conductors, see rules 273, 276, and 277.

For situations where such lines are carried over railways, see the special rules of section 26 which apply.

For special short span crossing construction, see rule 269.

(*b*) BETWEEN 750 AND 7500 VOLTS.—Supply lines between 750 and 7500 volts, in urban districts, where alone, shall be of grade C (see secs. 21, 22, and 23), and shall comply with the general rules of sections 20, 24, and 25, as to isolation, guarding, clearances, and pole arrangement.

Such lines, where crossing above other supply lines not exceeding 7500 volts, or conflicting with the latter, or on the same poles, are subject to grade C requirements for conductor stringing and strength of supports, and shall in other respects comply with the general rules of sections 20, 24, and 25.

For clearances of such lines from streets, roadways, and conductors or wires crossed, see rule 275 below.

For situations where such lines cross over, conflict, or are on the same supports with signal lines, see section 21, and the special rules of sections 26 and 28 which apply.

For situations where such lines are carried over overhead trolley contact conductors, see rules 273, 276, and 277.

For situations where such lines are carried over railways, see the special rules of section 26 which apply.

For special short span crossing construction, see rule 269.

(*c*) OVER 7500 VOLTS.—Supply lines over 7500 volts, in urban districts, where alone, shall be of grade B (see secs. 21, 22, and 23) and shall comply with the general requirements of sections 20, 24, and 25, as to isolation, guarding, clearances, and pole arrangement.

Such lines, where crossing above other supply lines or conflicting with the latter or on the same poles, are subject to grade B requirements for conductor stringing and strength of supports, and shall, in other respects, comply with the general rules of sections 20, 24, and 25 as to isolation, guarding, clearances, and pole arrangement.

For situations where such lines cross over, conflict, or are on the same supports with signal lines, see section 21, and the special rules of sections 26 and 28 which apply.

For situations where such lines are carried over overhead trolley contact conductors, see rules 273, 276, and 277.

For situations where such lines are carried over railways, see the special rules of section 26 which apply.

For clearance of such lines from streets, roadways, and conductors or wires crossed, see rule 275.

For special short span crossing construction, see rule 269.

272. Supply Lines in Rural Districts

(*a*) Below 7500 Volts.—Supply lines below 7500 volts, in rural districts, are subject to no special requirements for conductor stringing or strength of supports, but shall comply with the general rules of sections 20, 24, and 25, as to isolation, guarding, clearance, and pole arrangement.

For situations where such lines cross over, conflict, or are on the same supports with signal lines, see section 21 and the special rules of sections 26 and 28 which apply.

For situations where such lines are carried over overhead trolley contact conductors, see rules 273, 276, and 277.

For situations where such lines are carried over railways, see the special rules of section 26 which apply.

For clearances of such lines from streets, roadways and conductors, or wires crossed, see rule 275.

For special short span crossing construction, see rule 269.

(*b*) Above 7500 Volts—General.—Supply lines above 7500 volts in rural districts where alone or crossing over only such other supply lines as are over 750 volts or conflicting or on the same poles with the latter, are subject to no special requirements for conductor stringing or strength of supports, but shall comply with the general rules of sections 20, 24, and 25, as to isolation, guarding, clearance, and pole arrangement.

For situations where such lines cross over, conflict, or are on the same supports with signal lines, see section 21 and the special rules of sections 26 and 28 which apply.

For situations where such lines are carried over overhead trolley contact conductors, see rules 273, 276, and 277.

For situations where such lines are carried over railways, see the special rules of section 26 which apply.

For clearances of such lines from streets, roadways, and conductors or wires crossed, see rule 275.

For special short-span crossing construction, see rule 269.

(*c*) Above 7500 Volts and Exposing Lines below 750 Volts.—Supply lines above 7500 volts, in rural districts, crossing over, conflicting with, or on the same poles with supply lines below 750 volts, shall comply with grade C requirements (see secs. 21, 22, and 23), and shall comply with the general rules of sections 20, 24, and 25, as to isolation, guarding, clearances, and pole arrangement.

For situations where such lines cross over, conflict, or are on the same supports with signal lines, see section 21 and the special rules of sections 26 and 28 which apply.

For situations where such lines are carried over overhead trolley contact conductors, see rules 273, 276, and 277.

For situations where such lines are carried over railways, see the special rules of section 26 which apply.

For clearances of such lines from streets, roadways, and conductors or wires crossed, see rule 275.

For special short span crossing construction, see rule 269.

273. Strength of Supply Lines (not elsewhere covered)

(*a*) Supply Lines over Trolley Contact Conductors.—Supply conductors carried over trolley contact conductors shall conform to the same requirements as where crossing over supply lines of equal voltage, whether in urban or rural districts.

(*b*) Supply-Service Leads Over Trolley Contact Conductors Below 750 Volts.—Where supply-service leads under 750 volts are carried over trolley contact conductors under 750 volts, they shall be not less than No. 8 if soft copper, No. 10 if hard or medium copper, and No. 12 (Stl. W. G.) if galvanized steel. If spans exceed 150 feet, the size shall be not less than that required for grade C supply lines.

The sags of conductors where (*b*) applies shall be not less at 60° F than 12 inches up to 100 feet span, 18 inches up to 125 feet span, and 27 inches up to 150 feet span. For longer spans the sags shall be those required for grade C.

(*c*) SUPPLY-SERVICE LEADS OVER TROLLEY CONTACT CONDUCTORS ABOVE 750 VOLTS.—Where supply-service leads under 750 volts are carried over trolley contact conductors above 750 volts, the construction shall in all respects conform to the mechanical requirements of grade C in urban districts, and, where trolley is above 7500 volts, to grade B in urban districts and grade C in rural districts.

(*d*) SUPPLY-SERVICE LEADS IN URBAN DISTRICTS.—Supply-service leads under 750 volts not concerned in crossings with trolley contact conductors nor with other lines exceeding 750 volts shall conform to the requirements of rule 221 *d* as to conductor size. The sags at 60° F shall be not less than 12 inches up to 100 feet span, 18 inches up to 125 feet span, and 27 inches up to 150 feet span.

For longer spans the conductor size shall be increased and the sags shall be those required under grade C for the smallest conductor size listed in the sag tables of Appendix A for the material concerned.

(*e*) CABLED SERVICE LEADS.—In lieu of separate conductors supply-service leads may be grouped together in a cable, no individual conductor of which should be of less size than permitted for separate conductors. The sags should be the same as is required in (*d*), above, for the individual conductors where carried separately.

274. Special Longitudinal Strength Requirements in Urban Districts

(*a*) AT CROSSINGS.—Special longitudinal strength requirements are made for supply lines crossing over other supply lines in urban districts only where the crossover conductors exceed 7500 volts.

Even in this case (where grade B is required for the supply conductors by rules 217 and 271 *c*) no special longitudinal strength requirements are made at crossings if the supply line over 7500 volts maintains the same transverse strength at both sides of the crossing which it has at that point and continues in approximately the same direction.

In the case, however, where the supply line over 7500 volts changes its direction at either side of the crossover span and near the crossover, or where, by reason of passing into a rural district, the construction of grade B is not continued beyond the crossover span at one side, the longitudinal strength requirements of rules 266 and 267 shall apply. Where it is difficult to increase the longitudinal strength, the longitudinal stresses should be reduced by increasing the conductor sags.

(*b*) At Dead Ends or at Changes in Line Direction.—Where supply lines over 7500 volts in urban districts come to dead ends or to changes in line direction (even where no crossing exists) the ends shall have construction complying with the longitudinal strength requirements of rule 266.

275. Clearances. (For relative levels, see rule 240 b)

(*a*) The clear space between the lowest overhead supply-line conductors, guy, span, or messenger wires and the crowns of streets, highways, alleys, or generally accessible spaces across or along (and above) which the former pass shall not be less than given below, at 60° F with no wind, where the conductor or wire has fixed supports where supply-line spans do not exceed 150 feet.

(1) Clearances above streets or alleys in urban districts or over the traveled way in rural districts:

	Feet
Guys, span, or messenger wires and supply lines less than 300 volts to ground...	18
The above clearance does not apply to guys not carried over but merely beside streets or alleys unless also over driveways. Over roadways to residence garages 10 feet is sufficient clearance.	
Supply lines 300 volts to ground up to 15 000 volts...	20
Supply lines 15 000 to 50 000 volts...	22
For clearances of trolley contact conductors and feeders, see rule 276.	

(2) Clearances along roadways in rural districts where not over the traveled portion of the roadway:

	Feet
Guy, span, or messenger wires and supply lines less than 300 volts to ground.....	15
The above clearance does not apply to guys not carried over but merely beside streets or alleys unless also over driveways. Over roadways to residence garages 10 feet is sufficient clearance.	
Supply lines, 300 to 15 000 volts...	18
Supply lines, 15 000 to 50 000 volts...	20
For clearances of trolley contact conductors and feeders, see rule 276.	

(3) Clearances above spaces or ways accessible to pedestrians only:

	Feet
Guys, span, or messenger wires and supply lines less than 300 volts to ground...	10
For guys, 8 feet is sufficient and no clearance is required for anchor guys not passing across footways nor for those parallel with sidewalk curbs where traffic guards are provided.	
Supply lines, 300 to 15 000 volts...	15
Supply lines, 15 000 to 50 000 volts...	17
For clearances of trolley contact conductors and feeders, see rule 276.	

(*b*) The clear space between the lowest overhead supply-line conductor, guy, span, or messenger wire and any other conductor or wire over which the former crosses (except for crossings between conductors and guy wires or span wires on the same poles, for which see rule 241) shall not be less than given below at 60° F with no wind where the upper conductor or wire has fixed supports and the sum of the distances from the point of intersection to the nearer supporting structure of each span does not exceed 100 feet.

TABLE 6

Wire Crossing Clearances in Feet

[The conductors of lines operating at the voltages indicated at heads of columns should, in general, be installed above those to the left of the rows where the clearance is given in the usual type. The insertion of a given clearance in italics indicates that the lines operating at the voltage given in the table above this clearance should not cross over lines at the voltage to the left of the italicized clearance.] The table for convenience also includes signal conductors (see sec. 28) and trolley contact conductors (see rules 273, 276, and 277).

Conductors crossed over	Conductors crossing above—				
	Signal	0 to 750 volts	750 to 7500 volts	7500 to 50 000 volts	Guys, messengers, span wires, lightning-protection wires, service loops [a]
Signal (including their cables and messenger)	2	4	4	6	2
0 to 750	*4*	2	2	4	2
750 to 7500	*4*	*2*	2	4	4
7500 to 50 000	*6*	*4*	*4*	4	6
Trolley contact conductors	4	4	6	6	4
Guys, messengers, span wires, lightning-protection wires, service loops	2	2	4	4	2

[a] Guys, span, and messenger wires may be either above or below the conductors by the given clearances.

(*c*) INCREASE IN CLEARANCES OF (*a*) AND (*b*).—(1) For spans over 150 feet the clearances given under (*a*) shall be increased by 1 inch for each 10 feet excess up to 300 feet and by 1 inch for each 20 feet of excess beyond 300 feet.

(2) For situations where the sum of the distances from the point of intersection of two supply-line spans to the nearest pole of each line exceeds 100 feet the clearances given under (*b*) shall be increased by 2 inches for each 10 feet of excess between 100 and 200 feet and by 2 inches for each 20 feet of excess beyond 200 feet.

(3) For voltages over 50 000 the clearances of (*a*) and (*b*) shall be increased at the rate of 0.5 inch per 1000 volts excess above 50 000.

(4) For suspension insulators in grade B crossings (supply lines over 7500 volts in urban districts) the initial clearances above lines crossed over shall be increased sufficiently above those given in (*b*) to prevent the clearances from being reduced by the breaking of a conductor in either adjoining span by more than 25 per cent below the values given in (*b*).

The arrangement of insulators so that they are restrained from displacement toward the crossing will avoid the necessity of any increase over the given tabular clearances.

(5) Clearance increases under paragraphs (1) to (4) above are cumulative.

276. Electric Railway Feeders and Contact Conductors

(*a*) Third Rails.—Third rails shall be protected where not on fenced rights of way by suitable overlapping guards composed of wood or other suitable material.

(*b*) Trolley Contact Conductor Supports.—All overhead trolley contact conductors shall be so supported and arranged that the breaking of a single conductor fastening will not allow the trolley conductor or live span wire or current-carrying connections to come within 10 feet from the ground or from any platform accessible to the general public. This does not apply to insulated feeder taps to or from trolley contact conductors.

(*c*) High-Voltage Contact Conductors.—Above 1500 volts in urban districts (where not on fenced rights of way) the trolley contact conductor shall be so suspended that if broken at a single point it can not fall within 12 feet from the ground or any platform accessible to the general public.

(*d*) Assuring Against Loss of Power at Railway Crossings.—Unless electric-railroad systems are protected by interlocking derails or gates at grade crossings with interurban or other heavy or high-speed railroad systems the trolley contact conductors shall either be arranged with live trolley guards of suitable construction or shall be at the same elevation above their own tracks throughout the crossing and next adjoining spans, with catenary construction for crossing spans exceeding 100 feet.

(*e*) Guards Under Bridges.—Where passing under steel bridges that are not sufficiently elevated to prevent a trolley pole from making contact with the bridge in case it leaves the contact conductor a substantial inverted trough or other guard of insulating material shall be so installed as to prevent the trolley pole from making an electrical connection between the contact conductor and the bridge structure. (See rule 248 *d*.)

(*f*) Span-Wire Insulation.—Span-wire insulation for trolley contact conductors shall comply with rule 252 *g*.

(*g*) Strength of Construction at Railway Crossings.—Trolley contact conductors and feeders and their supporting structures, where crossing over railways, shall conform to the strength requirements specified for supply lines under section 21 and rules 261 and 266.

(*h*) Strength of Construction in Urban Districts Generally.—The strength of trolley contact conductors, feeders, and of their supports, where located in urban districts, shall conform to that required for supply lines of equal voltage. (See rules 271–274.)

(*i*) Pole Clearances from Rails.—The clearance of trolley construction supports from the rails of railways crossed over shall comply with the requirements for supply-line supports under rule 262. (For clearance from the associated track rails see rule 270 *c*.)

(*j*) Wire Clearances Above Railways, Roadways, and Footways.—The clear space between the lowest overhead trolley contact conductor or feeder, or guy, span, or messenger wire and the heads of rails, crowns of streets, highways, or alleys over which the former passes shall not be less than the following at 60° F, with no wind. (See also rule 240.)

(1) Above track rails of electric and other railways where brakemen are permitted on top of cars:

	Feet
Trolley contact conductors	22
Trolley feeders paralleling the contact conductors on the same street or highway	25

Trolley feeders not paralleling contact conductors are considered as supply lines of equal voltage. (See rules of section 26.)

Guy or span wires are considered as trolley contact conductors so far as elevation is concerned.

Where 21 feet has been established in any community instead of 22 feet for trolley contact conductor clearance, this may be continued, if carefully maintained.

The elevation of the contact conductor should be the same in the crossing and next adjacent spans. (See rule 276 *d*.)

(2) Above streets or alleys, roadways, or footways, including track rails of railways where brakemen are not permitted on top of cars: Trolley contact conductors, 16 feet.

Trolley feeders are considered as supply lines of equal voltage (see rules of sec. 26) whether paralleling contact conductors or not.

Guy or span wires are considered as trolley contact conductors so far as elevation is concerned.

The 16 feet is the minimum clear height in the middle of the contact conductor span, and the point of support at the pole structure should be not less than 18 feet above the traveled way, thus allowing 2 feet for the total maximum sag in span wire and trolley contact conductor at 60° F.

(3) Above track rails to which the trolley contact conductors or feeders belong: If brakemen are permitted on top of cars, 22 feet.

Twenty-one feet may be used where established in any community due to physical limitations, such as height of subways through which the electric cars must pass, and the limit of safe variation in elevation of trolley pole.

Where subways, tunnels, or bridges require it, a less clearance of contact conductor above ground may be used locally, and the trolley-contact conductor should be very gradually graded from the regular construction down to the reduced elevation.

(*k*) Clearances of Contact Conductors from Other Wires at Crossings.—The clear space between the trolley-contact conductor and the lowest overhead conductor or wire crossing above shall be not less than the following at 60° F with no wind. (Trolley feeders are considered as supply lines of equal voltage. See secs. 26 and 28 and rule 275.)

	Feet
Signal lines	4
Supply lines, 0 to 750 volts	4
Supply lines, 750 to 7500 volts	6
Supply lines, 7500 to 50 000 volts	6
Guy, span, and messenger wires and service loops	4
If trolley-contact conductor is above 750 volts, no conductor should cross at less than	6
Unless the crossover conductors are beyond the reach of a trolley pole leaving the contact conductor or are suitably protected against damage from a trolley pole leaving the contact conductor, the clearance for trolley-contact conductors below 750 volts should be not less than	6

Trolley feeders are exempt from a clearance requirement from contact conductors at the same nominal potential and of the same system.

(*l*) Increased Clearance.—(1) The clearances of (*k*) apply to spans above contact conductors not exceeding 150 feet. For longer spans the clearances above given shall be increased by 1 inch for each 10 feet excess up to 300 feet and by 1 inch for each 20 feet excess beyond 300 feet.

(2) For voltages over 50 000 the clearance of (*k*) shall be increased by 0.5 inch per 1000 volts excess above 50 000.

(3) For suspension insulators in grade B supply-line crossings over trolley-contact conductors or feeders (grade B is required for supply lines over 7500 volts in urban districts) the initial clearances shall be increased sufficiently above those given in (*k*) to prevent the clearance from being reduced by the breaking of a conductor in either adjoining span by more than 25 per cent below the values of (*k*).

The arrangement of insulators so that they are restrained from displacement toward the crossing will avoid the necessity of any increase over the given tabular clearances.

(4) The clearances of paragraphs (1) to (3) above are cumulative.

277. Trolley Feeders as Supply Lines

Except where specifically exempted in these rules (as for clearances and elevation in rules for common use of poles in this section and in section 28) trolley feeders shall be considered and constructed in all respects as supply lines of equal voltage.

278. Constant-current Lines

Where supply lines only are concerned, constant-current lines are included with constant-potential lines and graded by the nominal full-load voltage of the circuit concerned.

For the grading of constant-current circuits where signal lines for public use are concerned, see rules 214, 215, and 216, and section 28.

279. Common Use of Poles by Different Supply Lines—Special Rules (for general requirements see rules 271 and 272 and for common use of poles by supply and signal lines and conflicts between these two classes of lines, see sec. 28)

(*a*) Poles or towers used in common by supply lines of different voltage classifications, including trolley feeders, whether owned by the same or different utilities, shall have all supply lines arranged as to relative levels, separations, and clearances according to the requirements of section 24. In general the lines of higher voltage should be placed above those of lower voltage, and this arrangement will often avoid the necessity for increasing the grade of construction of the cross arms, pins, and fastenings for the lower-voltage conductors. (See also rule 270 *b* as to establishment of levels throughout a given community.)

(*b*) Poles or towers used in common by supply lines, as noted in (*a*), shall have the grade of construction determined by section 21 for the highest voltage lines carried on such pole or tower, all conductors of all voltages being included in the computations of stresses on the pole or tower.

The crossarms, pins, and fastenings of conductors on poles or towers used in common by supply lines, as noted in (*a*), shall have the grade of construction determined by section 21 for the lines carried by the crossarm, pin, or fastening in question, according to their relation to other lines carried on the pole or tower.

The size and initial sag of each conductor shall be determined by its own voltage and the grade of construction required for it, according to its relation to other conductors carried on the pole or tower, by section 21.

(*c*) Where the lines carried by a pole or tower are in crossings over railways, in conflict with other pole lines or in crossings with other pole lines, requiring by section 21 a higher grade of construction than is required by consideration of the relations of the lines carried in common by the pole by (*b*) above, such higher grade of construction shall apply to pole or tower and to any conductors, their crossarms and fastenings, to which the higher grade applies.

Where on a commonly used pole the lower level conductors, their fastenings, pins, and crossarms are exempt from any specific grade of construction, by reason of their lower level on the commonly used structure, and are also exempt from requirement for specific construction grade or have a lower grade even where located in urban districts, the grade of construction determined for such conductors by section 21 will nevertheless apply to them, wherever such conductors cross over railways, or cross or conflict with signal conductors.

The different conductors on a commonly used pole may therefore be subject to different grades of construction requirements, the grade necessary for any crossarm or pole being the highest required for any conductor carried, by section 21.

(*d*) In all cases of commonly used poles, signal conductors, which have assumed the character of supply conductors, and trolley feeder conductors shall be considered as supply lines of equal voltage in determining the grade of construction of the commonly used structure, whether in rural or urban districts, or in crossings with railways, or in crossings or conflicts with other pole lines.

(*e*) Where a trolley contact conductor is supported on a commonly used pole, it shall be included in the computation of transverse stresses on the structure, in accordance with section 23.

(*f*) The special requirements for longitudinal strength detailed in rule 266 shall apply to the common pole line structures and to all conductors at crossings of the common pole line over railways or over other lines, where these crossings require either grade A or grade B construction of the crossover span. These special requirements shall also apply to the common pole line, wherever of grade A or B construction, if by reason of change of direction, dead end, or the termination of an urban district and a consequent change in the common pole line construction to a lower grade, the stresses in the conductors are not balanced on both sides of a structure in the line.

Sec. 28. SIGNAL LINES AT CROSSINGS, CONFLICTS, AND COMMONLY USED POLES

A. SIGNAL LINES CROSSING OVER RAILWAYS

280. Signal Lines Crossing Over Important Railways (Described in rule 213), grade D

Signal lines crossing above railways, except unimportant railways and street railways on the traveled way of streets or highways (see rule 213), shall have construction in accordance with the following rules. Where crossing over supply lines (or signal lines having the character of supply lines) in the same span, the construction required shall be either grade D, or grade A, or B, according to the voltage of the supply line (see sec. 21). It is not intended that signal lines crossing over supply lines, covered in rule 216, and also crossing over railways in the same span, should have grade C rather than grade D requirements for supporting structures, but grade C requirements apply to conductor sizes and sags in such cases. (See rule 221 *e*.)

(*a*) Poles should, where practicable, be so located that crossing and adjacent spans are in a straight line and free from exposure by overhanging or closely adjacent trees or inflammable material or structures.

Poles or towers supporting the crossover spans of overhead signal lines over railways shall, unless physical conditions or municipal requirements prevent, have side clearance not less than 12 feet from the nearest track rail, except that at sidings a clearance not less than 7 feet may be allowed. At loading sidings sufficient space shall be left for a driveway.

(*b*) The length of the crossing span shall be as short as practicable, and in general, shall not be greater than the normal span of the line. No crossing span should exceed 150 feet in length, if this can be avoided. Whenever practicable, the difference in elevation of the wire supports at the crossing poles and the poles next adjacent shall not be greater than 5 feet.

(*c*) The vertical clearance between conductors supported on the same pole or structure and at different levels shall preferably be 24 inches, but in no case less than 12 inches (see also rule 243).

The clear space between the lowest signal conductor or guy, span, or messenger wire and the heads of rails over which the former pass, shall not be less than given below, at 60 ° F, with no wind, where the span does not exceed 100 feet.

	Feet.
(1) Where freight cars are handled and brakemen permitted on top. This may be reduced to 25 feet when paralleled by trolley contact conductors on the same street or highway.	27
(2) All other track rails	18

The clear space between the lowest signal conductor or guy, span, or messenger wire and the highest conductor, guy, span, or messenger wire (of the railway) passed over, shall not be less than given in rule 240 *b* at 60° F, with no wind, where the span does not exceed 100 feet.

For spans exceeding 100 feet the clearance should be increased 1 inch for each 10 feet excess over 100 feet.

(*d*) Wood poles supporting the crossing span shall be of selected timber, sound and reasonably straight. The minimum sizes of poles for different numbers of wires shall be as follows:

Not exceeding 20 wires	20 inches top circumference.
Over 20 but not exceeding 40 wires	22 inches top circumference.
Over 40 but not exceeding 80 wires	24 inches top circumference.

(*e*) The poles supporting the crossing span shall be head-guyed away from the crossing span and side-guyed in each direction. The number and size of guys shall be not less than given in the following table, and for spans longer than 150 feet shall be proportionally increased.

TABLE 7

Number of wires in crossing span	Number and nominal ultimate tensile strength in guys	
	Head guys	Side guys (in each direction)
1 to 10 wires	One 4000-pound cable	One 4000-pound cable.
11 to 20 wires	One 6000-pound cable	One 6000-pound cable.
21 to 40 wires	One 10 000-pound cable	One 10 000-pound cable.
41 to 60 wires	One 16 000-pound cable	One 16 000-pound cable.
61 to 80 wires	Two 10 000-pound cables	Two 10 000-pound cables.

A different arrangement and number of guys than specified in (*e*) may be used, provided equivalent strength is obtained.

In calculating side guying, the number of open wires which shall be considered equivalent to a cable is determined by multiplying the diameter of the cable, in inches, by three. For head guying, cables are not included in the count of wires, since the messenger serves as a head guy.

(*f*) Guy anchors shall, where possible, be located so that the horizontal distance from the ground line of the pole to the guy or guy rod will be not less than the height above ground of the attachment of the guy to the poles, for head guys, and not less than one-third that height, for side guys. Where the anchor for the head guy is located nearer to the pole than this distance, the amount of guying shall be increased to provide equivalent strength. The guys shall be attached as near to the center of the load as practicable.

(*g*) Where on account of physical conditions it is impracticable to guy the crossing poles as specified in (*e*), the requirements of that paragraph may be met by head guying and side guying the line as near as practicable to the crossing, but at a distance not exceeding 500 feet from the nearest crossing pole, provided that the line is approximately straight and that a cable of strength equivalent to that of the head guy is run between the two guyed poles, being attached to the guyed poles at the point at which the head guys are attached, this cable being securely attached to every pole between the guyed poles.

Where the poles supporting the crossing span are not in line with the poles in the adjoining spans, additional guying shall be placed to take care of the increased stress.

Braces may be used instead of guys to provide the reinforcement above specified.

(*h*) Wooden crossarms carrying the crossing span shall be of yellow pine, fir, or other suitable timber and shall have a minimum section of 2¾ by 3¾ inches for 6-foot arms or shorter and 3 by 4¼ inches for arms longer than 6 feet. Galvanized or painted iron, or steel crossarms, of equal strength may be used.

In rural districts having dry climates where the practice has been established of using 2¾ by 3¾ inch arms in 8 and 10 pin lenths, this practice may be continued where conductors are not larger than No. 10 A. W. G.

Crossarms and insulators shall be double on the crossing poles. The crossarms shall be held together with properly fitted spacing blocks or bolts placed immediately adjoining the outside pins and shall not support more than 10 conductors. Wood brackets shall not be used.

(*i*) Insulator pins shall be of steel, wrought iron, malleable iron, or locust or equivalent wood. Wood pins shall be sound and straight grain, with a minimum diameter of shank of 1¼ inches and a maximum length of 8 inches. Steel or iron pins shall have a minimum diameter of shank of one-half inch and a maximum length of 8¾ inches.

(*j*) Each insulator shall be of such pattern, design, and material that when mounted it will withstand without injury and without being pulled off the pin the ultimate strength of the conductor attached to the insulator.

(*k*) Conductors shall be of hard-drawn copper, copper-covered steel, galvanized steel, or other hard-drawn, corrosion-resisting metal, provided, however, that galvanized steel shall not be used in localities where excessive corrosion would result.

The minimum allowable sizes for conductors of the crossing spans are as follows:

Hard-drawn copper.—Spans 125 feet or less, No. 10 A. W. G.; spans 125 to 150 feet, No. 9 A. W. G.

Galvanized steel.—Spans 125 feet or less, No. 10 Stl. W. G.; spans 125 to 150 feet, No. 8 Stl. W. G.; No. 12 steel wire may be used in rural districts of arid regions, in spans of not to exceed 125 feet.

Steel-reinforced aluminum.—Spans 150 feet or less, No. 6 A. W. G.

If spans in excess of 150 feet are necessary, the size of conductors specified above shall be increased.

Conductors, of material other than copper, shall be of such size and so erected as to have a mechanical strength not less than that of the sizes of copper conductors given above.

(*l*) The use of twisted pair wires without a messenger-wire support shall be eliminated as far as practicable. In no case shall this kind of wire be used in spans longer than 100 feet without a messenger-wire support. Each wire of a twisted pair not supported by a messenger wire shall be tinned hard-drawn copper not smaller than No. 14 A. W. G., or tinned copper-covered steel not smaller than No. 17 A. W. G.

(*m*) Conductors of the crossing span shall be strung with sags not less than shown in the following table:

TABLE 8

Hard-Drawn Bare Copper Wire or Steel

Length of span	Sag at 20° F	Sag at 60° F	Sag at 100° F
No. 10 A. W. G. size:	Inches	Inches	Inches
80 feet	2½	4½	8½
90 feet	3½	5½	10
100 feet	4½	7	12
110 feet	5½	8½	14
120 feet	6½	10	16
No. 9 A. W. G. size or larger:			
130 feet	9	12	21
140 feet	10	15	22
150 feet	12	18	25

(*n*) The following table gives the minimum size of galvanized steel strand messenger cable to be used for supporting different sizes of cable:

TABLE 9

Size of multiple wire cable—		Messenger cable (nominal ultimate tensile strength)
No. 22 gage	No. 19 gage	
		Pounds
100 pairs or less.	50 pairs or less.	6000
110 to 200 pairs.	55 to 100 pairs.	10 000
Over 200 pairs.	Over 100 pairs.	16 000

For spans exceeding 200 feet a larger messenger cable shall be used.

(*o*) Multiple wire cables and their messengers shall be suspended with a minimum normal sag at 60° F, as follows:

TABLE 10

Length of span	Minimum sag	Length of span	Minimum sag
	Inches		Inches
80 feet or less	16	130 feet	34
90 feet	20	140 feet	40
100 feet	22	150 feet	44
110 feet	26	175 feet	62
120 feet	30	200 feet	82

281. Signal Lines Crossing Over Unimportant Railways (of the kinds described in rule 212 a), grade E

Signal lines crossing above unimportant railways as described in rule 212 shall have construction in all respects in accordance with the requirements of grade D, except as follows:

(*a*) Wood poles supporting the crossing span shall be of selected timber, sound and reasonably straight (see 280 *d*). The minimum sizes of poles for different numbers of wires shall be as follows:

Not exceeding 20 wires	18 inches top circumference.
Over 20 but not exceeding 40 wires	20 inches top circumference.
Over 40 but not exceeding 80 wires	22 inches top circumference.

(*b*) The poles supporting the crossing span shall be head guyed away from the crossing span and side guyed in each direction. The number and size of guys shall be not less than given in the following table, and for spans longer than 150 feet shall be proportionally increased. (See rule 280 *e*.)

TABLE 11

Number of wires in crossing span	Number and nominal ultimate tensile strength of guys	
	Head guys	Side guys (in each direction)
1 to 20 wires	None	None.
21 to 40 wires	One 6000-pound cable	One 6000-pound cable.
41 to 60 wires	One 10 000-pound cable	One 10 000-pound cable.
61 to 80 wires	One 16 000-pound cable	One 16 000-pound cable.

A different arrangement and number of guys than specified above may be used, provided equivalent strength is obtained.

In calculating side guying the number of open wires which shall be considered equivalent to a cable is determined by multiplying the diameter of the cable, in inches, by three. For head guying, cables are not included in the count of wires, since the messenger serves as a head guy.

(*c*) Wooden crossarms carrying the crossing spans shall be of yellow pine, fir, or other suitable timber and shall either have a minimum section of 3 by 4¼ inches or if smaller shall be double on the crossing poles and held together by properly fitted spacing blocks or bolts placed immediately adjoining the outside pins.

Crossarms shall not support more than 10 conductors; wood brackets shall not be used; galvanized or painted iron or steel crossarms of equal strength may be used. (See rule 280 *h*.)

(*d*) Conductors shall be of hard-drawn copper, copper-covered steel, galvanized steel, or other hard-drawn, corrosion-resisting metal, provided, however, that galvanized steel shall not be used in localities where excessive corrosion would result. (See rule 280 *k*.)

The minimum allowable sizes for conductors of the crossing spans are as follows:

Hard-drawn copper.—Spans 125 feet or less, No. 12 A. W. G.; spans 125 to 150 feet, No. 10 A. W. G.

Galvanized steel.—Spans 125 feet or less, No. 12 Stl. W. G.; spans 125 to 150 feet, No. 10 Stl. W. G.

Steel-reinforced aluminum.—Spans 150 feet or less, No. 6 A. W. G.

If spans in excess of 150 feet are necessary, the size of conductors specified above shall be increased.

Conductors of material other than copper shall be of such size and so erected as to have a mechanical strength not less than that of the sizes of copper conductors given above.

(*e*) The use of twisted pair wires without messenger-wire support shall be confined to spans not exceeding 150 feet. Each wire of a twisted pair not supported by a messenger shall be tinned hard-drawn copper not smaller than No. 14 A. W. G., or tinned copper-covered steel not smaller than No. 17 A. W. G (See rule 280 *l*.)

B. SIGNAL LINES CROSSING OVER SUPPLY LINES

282. Signal Lines Crossing over Trolley Contact Conductors

(*a*) NOT EXCEEDING 750 VOLTS.—(1) Signal lines carried over trolley contact conductors below 750 volts shall have grade C construction as to conductor sizes and sags except for twisted pair conductors, see (2); and except that for spans not exceeding 100 feet No. 12 A. W. G. hard-drawn copper or steel is permitted with a sag of not less than 12 inches; for spans between 100 and 125 feet No. 10 is permitted with a sag not less than 15 inches, and for spans between 125 and 150 feet No. 9 is permitted with a sag not less than 18 inches.

Where the signal lines concerned cross over railways under circumstances requiring grade D or E construction for signal lines, the requirement of the above rule applies as to size and sag of conductors, while grade D or E applies to the supporting structures.

(2) Twisted pair conductors, not supported by messengers, shall not be used in spans over 100 feet, if carried over trolley contact conductors below 750 volts, unless each wire is hard-drawn copper not less than No. 14 or copper-covered steel not less than No. 17.

(3) The clearance of signal lines above contact conductors crossed over shall be in accordance with the values given in the table of rule 240 *b*.

(*b*) Exceeding 750 Volts.—(1) For signal lines carried over trolley contact conductors above 750 volts in urban districts their strength of construction shall conform to the requirements of grade A, B, or C construction according as determined by rules 214, 215, and 216 for supply conductors of equal voltage, noting that for alternating-current contact conductors below 5000 volts in rural districts no specific grade of construction applies, and that for alternating-current trolley contact conductors between 750 and 5000 volts in urban districts, grade C applies except as to conductor sizes which may be reduced to the sizes listed in (*a*) (1) above.

The requirements for grades A, B, and C signal lines are given in detail in sections 22 and 23 and in rule 283 below.

(2) Twisted pair conductors may be used under the restrictions given in (*a*) (2) above, but if in A or B construction, they shall have sags not less than those required by section 22 for No. 8 hard-drawn copper, and where supported by a messenger, the messenger shall have the sags required in rule 280 (*o*). Where supply line voltage exceeds 7500 volts the twisted pair shall always be supported by a messenger.

(3) The clearances of signal lines above the contact conductors crossed over shall be in accordance with the values given in the table of rule 240 *b*.

283. Signal Lines Crossing over Supply Lines Above 750 Volts (not recommended except over trolley feeders)

(*a*) Strength of Construction.—Overhead signal lines crossing over supply lines under the circumstances noted in item (*b*) of rules 214, 215, and 216 shall have construction of grade A, B, or C as required in those rules. (See rule 210 for signal lines not for public use.)

(*b*) Compliance with other Rules.—Where signal lines crossing over supply lines are of grade A, B, or C construction, they shall conform as to conductor sizes, materials, and sags with the requirements of section 22; as to materials and strength of supporting structures and attachments with section 23; as to separation and clearances of conductors and wires of the signal lines themselves with the requirements of section 24; as to guys and their insulators with the requirements of section 25, and in general with the requirements of sections 20 and 25.

(*c*) Where Concerned also with other Overhead Lines or with Railways.—Such signal lines, where also concerned at the crossover in conflicts or common use of poles with other lines, or in crossovers over railways, shall conform to the requirements of rule 210 as to relative level, and with rules 211 to 219 as to character of construction, and with the rules of sections 26, 27, and 28 which apply to these other conditions, in addition to the requirements of this rule.

Where such signal lines are of grade C construction and also cross over railways under circumstances calling for grade D or E construction for the signal lines, the requirement for grade C construction may be waived as to strength of supports, being replaced by those of grades D or E, but grade C requirements apply as to size and sag of conductor. (See rule 221 *e*.)

(*d*) POLE CLEARANCE.—The pole or tower structures of each line concerned in the crossover shall have clearances from the conductors of the other line (unless attached) as required by rule 245 *a* and *c*.

(*e*) WIRE CLEARANCE ABOVE SUPPLY LINES.—The clear space between the lowest overhead signal line conductor or guy, messenger, or span wire crossing over any supply line conductor or guy, span, or messenger wire (except for crossings between conductors and guy, messenger or span wires on the same pole, for which see rule 241) shall not be less than given below, at 60° F with no wind where the upper conductor or wire has fixed supports, and the sum of the distances from the point of intersection to the nearest supporting structure of each span, does not exceed 100 feet.

	Feet.
Signal lines above supply conductors below 7500 volts	4
Above supply conductors 7500 to 50 000 volts	6
Above supply service conductors	2
Above supply guy, messenger, and span wires	2
Guy, span, and messenger wires above supply conductors below 750 volts	2
Above supply conductors 750 to 7500 volts	4
Above supply conductors 7500 to 50 000 volts	6

(*f*) CLEARANCE INCREASE FOR LONG SPANS.—The clearances of (*e*) shall be increased where the sum of the distances from the point of intersection to the nearest supporting structure of each span exceeds 100 feet, by 2 inches for each 10 feet of the excess between 100 and 200 feet, and by 2 inches for each 20 feet of the excess beyond 200 feet.

(*g*) CLEARANCE INCREASE FOR HIGH VOLTAGE.—The clearances of (*e*) shall be increased, where the supply line voltage exceeds 50 000 volts, by 0.5 inch per 1000 volts excess.

(*h*) Falling Trees.—The crossing span and the next adjoining spans, so far as practicable, shall be kept free from overhanging or decayed trees, which might fall into the line. (See also rules 250 *d* and 257.)

(*i*) Special Requirements for Crossing Sections of Grades A and B Construction in Signal Lines of a Lower Grade of Construction.—For special requirements for longitudinal strength of crossover supports of signal lines crossing over supply lines, where grade A or B are required for the signal lines, see rule 266.

(*j*) Special Short Span Crossovers.—For special short span crossing construction, see rule 269.

(*k*) Guys.—Guys may be used to meet the strength requirements of section 23, and where used they and their insulators and guards shall conform to the requirements of section 25.

C. SUPPLY AND SIGNAL LINE CONFLICTS

284. Signal Lines Conflicting with Supply Lines

(*a*) Strength of Construction.—Where signal lines are at higher levels and conflict with supply lines the requirements of rule 283 *a* and *b* apply in general to the conflicting signal lines just as they apply where the signal lines cross over the same supply lines.

(*b*) Where Concerned also with other Overhead Lines or with Railways.—Such signal lines where also concerned at the conflict, in crossings over other lines or over railways, or in common use of poles with other lines, shall conform to the requirements of rule 210 as to relative level, and with rules 211 to 219 as to character of construction, and with the rules of sections 26, 27, and 28 which apply to these other conditions, in addition to the requirements of this rule. (See also rule 283 *c* second paragraph.)

(*c*) Pole Clearance.—Where conductors of one line are carried within 6 feet from a supporting structure of a conflicting line (the second line), and are not attached thereto, the conductors of the first line should be spaced at least as far from all surfaces of structures of the second line as required by rules 241 and 242 for separation between conductors of the circuit concerned. This minimum clearance shall be increased by 1 inch for each 2 feet distance between the supporting structure of the second line and the nearest supporting structure of the first line.

(*d*) Clearance of Conductors of Two Conflicting Lines.—The minimum clearance in any direction from any conductor of one line to any conductor of a second and conflicting line shall be 4 feet. In no case should the clearance be less than the values required by rules 241 and 242 for separation between similar conductors on the same support, increased (where at approximately the same level) by 1 inch for each 2 feet of the distance from the middle of span of the first line to the middle of the span of the second line.

(*e*) Guys.—Guys may be used to meet the strength requirements of section 23, and where used they and their insulators and guards shall conform to the requirements of section 25.

(*f*) Special Requirements for Ends of Sections of Grade A or B Construction in Signal Lines Elsewhere of a Lower Grade.—For special requirements for longitudinal strength of supports for ends of sections of grade A or B construction, in lines of a lower grade, see rule 266.

The end of a grade A or B section might occur where the conflict with supply lines came to an end.

285. Supply Lines Conflicting with Signal Lines

(*a*) Strength of Construction.—Where supply lines are at higher levels and conflict with signal lines, the requirements of rule 268 apply in general to the conflicting supply lines, just as they apply where the supply lines cross over the same signal lines.

(*b*) Where Concerned also with Other Overhead Lines or with Railways.—Such supply lines where also concerned at the conflict in crossings over other lines or over railways, or in common use of poles with other lines, shall conform to the requirements of rule 210 as to relative level, and with rules 211 to 219 as to character of construction, and with the rules of sections 26, 27, and 28, which apply to these conditions, in addition to the requirements of this rule.

(*c*) Pole Clearance.—The clearance from the poles of one line to the conductors of a second line, where the two lines conflict, shall comply with the requirements of rule 284 *c*.

(*d*) Clearance of Conductors of Two Conflicting Lines.—The clearance in any direction between conductors of two conflicting lines shall comply with the requirements of rule 284 *d*.

(*e*) Guys.—Guys may be used to meet the strength requirements of section 23, and where used they and their insulators and guards shall conform to the requirements of section 25.

(*f*) Special Requirements for Ends of Sections of Grade A or B Construction in Supply Lines elsewhere of a Lower Grade.—For special requirements for longitudinal strength of supports for ends of sections of grade A or B construction, in lines of a lower grade, see rule 266.

The end of a grade A or B section might occur where the conflict with signal lines came to an end.

D. COMMONLY USED LINES

286. Common Use of Poles or Towers by Signal and Supply Lines (Including Trolley Feeders and Contact Conductors—Supply Lines above Signal Lines)

Two parallel pole lines, unless both carry only signal lines, shall, where practicable, be so separated from each other that neither conflicts with the other. (See definition 41.) If this can not be done, the two pole lines shall be separated as far as practicable. (See also rule 245.)

It is recommended that overhead lines which can not readily be so separated from each other as not to conflict be placed on a single common pole line unless the high voltage of certain circuits or the large number of conductors makes the use of a single-pole line undesirable or impracticable.

(*a*) Strength of Construction.—(1) Poles or towers commonly used by supply lines and signal lines for public use with the supply lines above shall have the highest grade of construction specified in rules 214, 215, and 216, according to the voltage and character of the various lines carried by the pole or tower.

Where the signal lines are not for public use, the pole strength need not be that required where those for public use are concerned, but the lines shall occupy the same relative positions noted under (*b*) below. (See also rule 210 *c*–3.)

(2) The strength of crossarms, pins, and fastenings shall conform to the highest grade of construction required for the lines carried by the particular crossarm concerned, according to rules 214, 215, and 216. This may sometimes be a lower grade than that required for the pole or tower by reason of other lines carried on higher crossarms.

(3) The construction of the pole or tower structure shall also be of stronger grade (than required because of its common use by supply and signal lines) if crossings of the common pole line over railways call for such stronger grade.

(4) The special requirements for longitudinal strength detailed in rule 266 shall apply to the common pole-line structure at its crossings over railways or other lines where these crossings would of themselves require either grade A or grade B construction of the crossover span. These special requirements shall also apply to the common pole line, if of grade A or B construction, wherever, by reason of change of direction, dead end, or the termination of signal lines and a change in the line construction to a lower grade, the stresses in the conductors are not balanced on both sides of a structure in the line.

(5) In calculating the transverse pressures upon poles carrying supply conductors above signal conductors, where no supply conductors are below signal conductors, the number of signal conductors upon which the transverse pressure is calculated shall be taken as only one-half their total number, provided that they are smaller than No. 8 A. W. G.

There are two reasons for this exception: (1) Signal conductors of small size and strung to small sags are more liable to break and relieve transverse pressure than are larger supply conductors so strung; (2) common use of poles will be encouraged and thus hazards be avoided which would exist were two separate and frequently conflicting pole lines used to limit the number of wires.

(6) In calculating the longitudinal stresses upon commonly used poles of grade A or B construction where crossing over railways or over signal lines where these crossings would of themselves require grade A or B construction of the crossover span to meet the special longitudinal requirements at such points the tension in the signal conductors may be considered as limited to one-half their breaking strength provided they are smaller than No. 8 A. W. G., regardless of how small the initial sags of the signal conductors at 60° F.

(*b*) Clearances and Separations and Relative Levels.—The clearances and separations of supply and signal conductors on commonly used poles as well as the relative levels are covered in detail in section 24, particularly in rule 240. In general, signal lines for public use should be not less than 4 feet below supply lines.

Where signal lines are below supply lines the requirements for grade A, B, or C, strength of their crossarms, pins, and fastenings are avoided.

The establishment of standardized levels in any given community, as recommended by rules 210 and 270, facilitates the extension of lines and the safety of the public and workers by permitting the desired relative levels and clearances to be readily obtained on commonly used poles as well as in crossings and conflicts.

(*c*) Pole Wiring.—Pole wiring, verticals and laterals, shall be run with the clearances or special protection required by the rules of section 24.

(*d*) Conformity with Other Rules.—In other respects the commonly used pole line shall conform to the general requirements of sections 20, 21, 24, and 25.

287. Common Use of Poles or Towers by Signal and Supply Lines (including Trolley Feeders and Contact Conductors—Signal Lines above Supply Lines)

(This relation of levels is not in general desirable, and should be avoided where practicable. See rule 286 *b*.)

Two parallel pole lines, unless both carry only signal lines, shall, where practicable, be so separated from each other that neither conflicts with the other. (See definition 41.) If this can not be done, the two pole lines shall be separated as far as practicable. (See also rule 245.)

It is recommended that overhead lines which can not readily be so separated from each other as not to conflict be placed on a single common pole line unless the high voltage of certain circuits or the large number of conductors makes the use of a single pole line undesirable or impracticable.

(*a*) Strength of Construction.—(1) The strength of poles or towers shall be of the grade specified in rules 214, 215, and 216, according to the voltage and character of the lines concerned. Whether the signal lines are for public use or not, the same strength requirements apply, where the signal lines are at the higher levels (see rule 210 *c*-3).

Constant-potential alternating-current supply lines over 750 volts or constant-current supply lines below 7.5 amperes in urban districts, where carried below signal lines for public use, call for grade C construction of the signal lines.

Trolley feeders over 750 volts direct-current or over 7500 volts alternating-current or supply lines of equal voltage and constant-current circuits over 10 amperes, carried below signal lines for public use, call for grade A construction of the signal lines.

Alternating-current trolley feeders between 5000 and 7500 volts, or alternating-current supply circuits between these voltages or constant-current circuits between 7.5 and 10 amperes, call for grade B construction of the signal lines.

(2) The grade of construction A, B, or C, where required for the signal lines, includes the size, material, and sagging of conductors of section 22 and the strength of structures required by section 23, with no reduction in transverse strength requirements such as is permitted by rule 286 *a*-5, where supply lines are above signal

lines, although with grade C signal lines a smaller size of conductor is permitted in short spans than specified in section 22.

For the smaller conductor sizes permitted for grade C signal lines in short spans, see rule 221 *e*.

(3) The grade of construction for the crossarms, pins, fastenings and conductors of supply lines beneath shall be only that required for their location in urban districts or for their crossings, conflicts, or common use of poles with the other supply lines on the same or other structures, or with signal lines on other structures, or for their crossings over railways, if any of these conditions exist.

(4) The grade of construction of the structure may be raised to a higher grade than called for by its common use by signal lines above supply lines where the common line crosses a railway and grade A is called for by the rules.

(5) The special longitudinal strength requirements, detailed in rule 266, shall apply to the common pole line structures at crossings over railways or other lines where the crossings would of themselves require either grade A or grade B construction of the crossover span. These special requirements shall also apply to the common pole line if of grade A or B construction wherever by reason of change of direction, dead end, or the termination of either supply or signal lines and a change in construction to a lower grade the stresses in the conductors are not normally balanced on both sides of any structure in the line.

(*b*) Clearances and Separations.—The clearances and separations of supply and signal conductors on commonly used poles as well as the relative levels are covered in detail in section 24, particularly in rule 240. Signal conductors not for public use shall, however, where carried above supply conductors between 750 and 7500 volts, be carried at a level at least 4 feet above (instead of the 2 feet permitted by the table for the reversed positions), unless the conductor size is not reduced from that required for grade C supply lines.

(*c*) Pole Wiring.—Pole wiring, verticals and laterals, shall be run with the clearances or special protection required by the rules of section 24.

(*d*) Conformity with Other Rules.—In other respects the commonly used pole line shall conform to the general requirements of sections 20, 21, 24, and 25.

E. SIGNAL LINES ALONE

288. Signal Lines Alone (or concerned only with other signal lines)

(*a*) Fire-Alarm Lines.—Conductors used for fire-alarm circuits shall be of not less than No. 10 A. W. G. hard or medium copper, or in dry regions of not less than No. 10 galvanized steel. Sags shall be not less than 12 inches up to 100 feet span, 18 inches for spans between 100 and 125 feet, and 27 inches for spans between 125 and 150 feet. For longer spans larger conductors shall be used.

Where carried at higher levels than supply conductors in crossings, conflicts, or common use of poles, they shall have grade A, B, or C construction, according as rule 214, 215, or 216 applies.

(*b*) Other Signal Lines.—Conductors for other signal lines, unless at higher levels and crossing or conflicting with, or on the same poles above supply (or trolley) lines, are not required to conform to any requirements as to size, material, or sag.

(*c*) Supporting Structures for Signal Lines.—The material and strength of poles used for other signal lines, unless exposed to supply (or trolley) lines by crossing above, conflicting with, or being carried above the supply lines on the same poles, are not required to conform to any requirements as to strength and material of poles, except that poles and crossarms shall be of such initial size, and so guyed or braced where necessary as to safely withstand the vertical loads to which they may be subjected, including linemen working on them.

In other respects all signal-line supports shall conform to the general requirements of sections 20 and 25, covering traffic guards, pole clearances, guys, and other matters.

(*d*) Clearances Above Ground (see also rule 240 *a*).—Signal conductors alone and their guys, span wires, and messengers shall have clearances above streets, highways, alleys, or generally accessible spaces across or along (and above) which the former pass, not less than the following at 60° F., with no wind, when the spans do not exceed 100 feet.

Signal lines, or guy, span, or messenger wires:

	Feet
Above streets and other traveled roadways	18
Along roads in rural districts	15
Crossing above spaces or ways accessible only to pedestrians	10

The clearances do not apply to guys not carried over roadways, nor to guys along one side of a street or alley, unless over driveways. Over roadways to residence garages the guy clearance may be reduced to 10 feet. For guys on private right of way, or parallel to sidewalk curbs, when not passing over pathways or roadways, no clearance is required; and if passing over only pathways the clearance may be reduced to 8 feet.

For signal-line spans over 100 feet these clearances shall be increased at the rate of 1 inch for each 10 feet excess.

(*e*) CLEARANCES FROM OTHER SIGNAL LINES (see also rule 240 *b*).—Signal conductors and their guy, span, or messenger lines concerned in crossings, conflicts, or common use of poles with other signal lines only, shall have clearance in general from those other lines as follows:

Signal-line conductors or guy, messenger, or span wires to the conductors or guy, messenger, or span wires of other signal lines, 2 feet.

Except for fire-alarm lines this may be reduced where desired, unless one set of conductors is for public use and the other not for public use.

(*f*) GROUNDING, ISOLATION, OR PROTECTION.—Signal lines for public use, including fire-alarm lines, if at any point in their course exposed by supply (or trolley) lines over 400 volts to ground, shall be protected at each station for public use by one of the methods specified in Part 3, section 39. These lines shall elsewhere be isolated by elevation or otherwise guarded so as to be inaccessible to the public.

Signal lines not for public use shall be at *all* points isolated by elevation or otherwise guarded so as to be inaccessible to the public.

Metal-sheathed cables and messengers shall be isolated or grounded in conformity with the general requirements of section 20.

(*g*) SIGNAL LINES NOT FOR PUBLIC USE, WHERE ALONE.—Such lines in urban districts, unless either run in all respects as signal lines for public use and so considered at all exposures by supply (or trolley) lines, or in lieu of such precaution protected by suitable protectors according to the voltage of the highest voltage lines to which they are exposed and run always at lower levels than the supply lines, shall everywhere have mechanical strength in all respects equal to that which would be required for supply lines of the highest voltage to which the signal lines are exposed.

UNDERGROUND LINES

Sec. 29. MANHOLES, HANDHOLES, SPLICING CHAMBERS AND DUCTS, CONDUCTORS, AND EQUIPMENT

290. Location and Accessibility of Conduits and Manholes

(*a*) Underground systems of electrical conductors should be so located as to be subject to the least practicable amount of disturbances. When being designed and installed, care should be exercised to avoid catch basins, street railway tracks, gas pipes, or other underground structures.

(*b*) To facilitate installing and withdrawing cables and conductors, the ducts between adjacent manholes or other outlets should be installed in straight lines, except when it is necessary to install curves, in which case they should be of the greatest practicable radius, and the spacing between adjacent manholes should be correspondingly reduced.

(*c*) Manholes shall, where practicable, be so located as to provide convenient access and, if possible, so that the least horizontal distance from any rail of a railroad track to the nearest edge of a manhole opening is not less than 3 feet.

291. Grading of Ducts

Manholes or handholes should be so located and ducts so graded that drainage of ducts will always be toward manholes or handholes. To insure satisfactory drainage, the ducts shall be so installed as to provide, where practicable, a grade of not less than 3 inches in 100 feet of length.

292. Mechanical Details of Manholes

(*a*) The mechanical design and construction of manholes and handholes shall be such as to provide sufficient strength to safely sustain with a suitable margin of safety the mechanical loads which reasonably may be expected upon them.

(*b*) The entrance to all manholes shall be not less than 24 inches minimum diameter. Round openings are recommended.

(*c*) Manholes should be so constructed, when practicable, that the least inside horizontal dimensions will be not less than 3 feet 6 inches and should be so arranged as to maintain, if practicable, a clear working space not less than 3 feet horizontally and 6 feet vertically, except that where the opening is within 1 foot on each side of the full size of the manhole the depth may be less.

(*d*) Where surface or ground water is liable to enter manholes containing supply conductors, these shall be so arranged, if practicable, as to provide permanent drainage.

Where drainage is into sewers, suitable traps shall be arranged to prevent entrance of sewer gas into manholes.

Manholes shall have adequate ventilation to open air where this is practicable and can be arranged without permitting entrance into the manhole of surface water, and such ventilation shall always be provided where any opening exists from such chambers into subways entered by the public, as with some subway conduit systems.

293. Manhole Covers and Guards

(*a*) Manholes and handholes, while not being worked in, shall be securely closed by covers of sufficient strength to sustain such mechanical loads as may reasonably be expected to be imposed upon them, and the arrangement shall be such that a tool or appliance is required for their opening or removal..

(*b*) Manhole openings shall be so arranged that when they are uncovered barrier or other suitable guards may be placed to effectively protect the opening.

294. Material, Size, and Finish of Ducts

Ducts used in underground systems of distribution for electrical supply and signal conductors shall be of such material, size, mechanical strength, and finish as to facilitate the installation and maintenance of conductors or cables.

295. Installation of Conduits

(*a*) Ducts should be suitably reinforced or be laid on suitable foundations of sufficient mechanical strength where necessary to protect them from settling and should be protected by concrete or other covering where necessary to prevent their disturbance by workmen when digging or by other causes. The distance between the top of the conduit covering and the pavement surface or other surfaces under which the duct run is constructed shall be sufficient to protect the conduit from injury and shall generally be at least 30 inches to the under side of track rails beneath which conduit passes.

(*b*) Ducts shall have clear bores and be freed from burrs before laying. They shall be laid in line in such manner as to prevent shoulders at joints.

(*c*) Iron-pipe conduit terminating in manholes, handholes, or other permanent openings of underground systems shall be provided with an effective bushing or other smooth outlet.

(*d*) Duct runs should provide as great a clearance from other underground structures as practicable and particularly from gas lines paralleling them.

(*e*) Conduits for underground conduit systems to be occupied by signal conductors for public use should, where practicable, be separated from underground conduit systems for supply conductors by not less than 3 inches of concrete or its equivalent.

(*f*) Cable extensions may, however, be made to existing interconnected or jointly owned and jointly occupied duct systems used in common by municipalities, signal and power companies, with less effective separations than above specified.

(*g*) Where signal conductors for public use and supply conductors occupy ducts terminating in the same manhole, the two classes of duct should be separated as widely as practicable; and, where practicable, enter the manhole at opposite sides, so that cables can be racked along side walls with a minimum of crosses between the the two classes of conductors.

(*h*) Joints in duct runs shall be made mechanically secure to maintain individual ducts in alignment.

(*i*) Duct openings into manholes or handholes should, where practicable, have a clearance above the floor or below the roof line of not less than 6 inches.

(*j*) Ducts of laterals supplying service to buildings, where gas or water is liable to enter through them, should be effectively plugged or cemented by the use of asphaltum, pitch, or other suitable means.

(*k*) Conduits designed to carry supply cables of large current capacity should be arranged, where practicable, so that no ducts necessarily dissipate heat solely through adjacent ducts.

296. Location and Identification of Conductors

(*a*) Underground systems of electrical supply conductors and of signal conductors for public use should in general be maintained in separate conduits and manholes.

(*b*) Cable extensions to existing interconnected or jointly owned and jointly occupied duct systems used in common by municipalities, signal companies, and power companies are exempted from the above.

(*c*) When signal conductors for public use and electrical supply conductors occupy the same manholes, they should be maintained at opposite sides of the manhole; and where supply cables are of large current capacity all cables should be specially protected against injury by arcing. When it is necessary that the signal and supply cables cross in any manhole, a spacing of at least 1 foot shall be maintained and special mechanical protection provided against abrasion or injury by arcs.

(*d*) Cables shall be permanently identified by tags or otherwise at each manhole, handhole, or other permanent opening of the underground system, except where their position, in conjunction with diagrams supplied to workmen, give sufficient identification.

(*e*) Cables in manholes shall be reasonably accessible from the clear working space at all times. When cables cross by or over other cables, sufficient clearance shall be provided between them to permit reasonable access to any cable for inspection and repair and to prevent abrasion.

(*f*) Joints made in, or branches made from, underground cables should be reasonably accessible at all times and should be in manholes or handholes, and as seldom as possible in the ducts themselves.

(*g*) Each cable, where practicable, shall maintain a vertical clearance above the floor of any manhole of not less than 6 inches.

297. Mechanical Protection, Support, and Guarding of Live Parts

(*a*) Cables, unless rubber insulated, shall be provided with a water-tight metal sheath or other waterproof covering over their insulating coverings, except when used as ground connections or neutrals.

(*b*) Protective, control, or other apparatus on supply lines where installed and maintained in manholes and handholes shall have live parts inclosed in suitable cases. The metal sheathing of all conductors or cables shall be made mechanically and electrically continuous with the metal cases of protective, control, or other apparatus.

(*c*) Mechanical support shall be provided for all cables at each manhole, handhole, or other permanent opening. Where closely grouped lead-covered cables include cables operating at over 7500 volts, they should have suitable fire-resistive coverings to prevent damage from arcing.

Such protection is also frequently advisable where all voltages are less than 7500, especially where some of the cables are of large current capacity.

(*d*) Conductors or cables from underground systems which connect to overhead systems shall be mechanically protected by installing them in grounded metal conduit or, in the case of signal cable or metal-sheathed cable, in other substantial conduit, and shall terminate in suitable potheads or similar devices of approved design or construction; the open supply wiring connecting to the underground system shall begin not less than 10 feet above the ground surface or platform accessible to the public.

(*e*) Joints or terminals of conductors or cables of underground systems of electrical supply shall be so arranged that there are no bare ungrounded current-carrying metal parts exposed to accidental contact within manholes or handholes.

298. Spacing of Cables

(*a*) Cables shall be so arranged and supported in ducts and manholes that those of higher operating voltages are separated from those of lower voltages as far as practicable.

(*b*) Cables belonging to different systems (particularly supply distribution and signal systems) shall not be run in the same duct.

299. Multiple Connections

When transformers, regulators, or other similar apparatus operate in multiple, special tags or other suitable means shall be used to indicate that fact.

Appendix A.—LOADING DATA, MECHANICAL CHARACTERISTICS, AND RECOMMENDED NORMAL SAGS OF OVERHEAD LINE CONDUCTORS

While the following sags are those generally recommended, circumstances will sometimes call for modifications. For instance, where many large conductors are carried by a pole line, greater sags than those listed for the large conductors will sometimes be advisable, to reduce the stresses on poles at turns and dead-ends, and to permit smaller longitudinal guying at crossovers where such guying is called for by the rules.[7] (See rule 266.)

TABLE 12

Sags at 60° F for Medium and Hard Drawn Covered Copper Wires

(*a*) HEAVY-LOADING DISTRICTS

Size A.W.G.	Grades of construction	Span lengths: 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
		In.	In.	In.	In.	In.	In.	In.
No. 8	C	18	27	40				
No. 6	A	18	27	40				
	B	15	22	33				
	C	12	18	27	36			
No. 4	All	12	18	27	36	48		
No. 2	do	12	18	27	30	36	60	96
No. 1	do	12	18	26	29	33	52	80
No. 00	do	12	18	25	28	31	46	66
No. 0000	do	12	18	24	27	30	38	50

(*b*) MEDIUM-LOADING DISTRICTS

Size A.W.G.	Grades of construction	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
No. 8	C	15	22	33				
No. 6	A	15	22	33				
	B	12	18	27	36			
	C	10	15	22	30			
No. 4	All	10	15	22	30	39		
No. 2	do	10	15	22	27	32	50	76
No. 1	do	10	15	22	25	29	39	60
No. 00	do	10	15	22	24	26	33	48
No. 0000	do	10	15	22	23	24	29	40

[7] Sags for temperatures differing widely from 60° F and methods for computing sags are being included in a separate publication of the Bureau, shortly to be issued.

TABLE 12—Continued

(*c*) LIGHT LOADING DISTRICTS

Size A.W.G.	Grades of construction	Span lengths 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
		In.	In.	In.	In.	In.	In.	In.
No. 8	C	12	18	27	36	......	......	......
No. 6	A	12	18	27	36	......	......	......
	B	10	15	22	30	38	......	......
	C	8	12	18	24	32	......	......
No. 4	All	8	12	18	24	32	......	......
No. 2	do	8	12	18	22	26	34	52
No. 1	do	8	12	18	21	24	31	45
No. 00	do	8	12	18	20	22	28	37
No. 0000	do	8	12	18	19	21	25	32

TABLE 13

Sags at 60° F for Soft-Drawn Covered Copper Wires

(*a*) HEAVY LOADING DISTRICTS

Size A. W. G.	Grades of construction	Span lengths 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet
		In.	In.	In.	In.	In.	In.
No. 6	C	21	32	48	......	......	......
No. 4	A	21	32	48	......	......	......
	B and C	18	27	40	......	......	......
No. 2	A	18	27	40	54	......	......
	B and C	15	22	33	45	60	......
No. 1	A	15	22	33	45	60	......
	B and C	12	18	27	37	48	......
No. 00	All	12	18	25	33	42	......
No. 0000	do	12	18	24	30	36	......

(*b*) MEDIUM LOADING DISTRICTS

Size A. W. G.	Grades of construction	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet
No. 6	C	18	27	40	......	......	......
No. 4	All	15	22	33	48	......	......
No. 2	do	12	18	27	36	48	......
No. 1	do	12	18	25	33	42	60
No. 00	do	12	18	24	30	36	48
No. 0000	do	12	18	24	30	36	48

(*c*) LIGHT LOADING DISTRICTS

Size A. W. G.	Grades of construction	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet
No. 6	A	18	27	40	......	......	......
	B and C	15	22	33	......	......	......
No. 4	All	12	18	25	32	42	......
No. 2	do	10	15	21	27	36	48
No. 1	do	10	15	20	25	30	42
No. 00	do	10	15	20	25	30	42
No. 0000	do	10	15	20	25	30	42

TABLE 14

Sags at 60° F for Medium and Hard Drawn Bare Copper Wires

(*a*) HEAVY LOADING DISTRICTS

Size A. W. G.	Grades of construction	Span lengths										
		100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet	400 feet	500 feet	700 feet	1000 feet
		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
No. 8	C	12	18	27								
No. 6	A	12	18	27								
	B	10	15	22								
	C	10	15	22	33							
No. 4	All	10	15	21	28	38	71	115				
No. 2	do	10	15	18	21	24	44	68	138	228		
No. 1	do	10	15	18	21	24	40	59	120	204		
No. 00	do	10	15	18	21	24	36	50	102	168		
No. 0000	do	10	15	18	21	24	32	42	84	132		

(*b*) MEDIUM LOADING DISTRICTS

No. 8	C	8	12	18								
No. 6	All	8	12	18	24							
No. 4	do	8	12	18	24	32	42	69	141			
No. 2	do	8	12	18	22	26	36	50	88	150	324	
No. 1	do	8	12	18	21	24	31	40	72	124	286	
No. 00	do	8	12	18	20	22	27	33	55	92	192	415
No. 0000	do	8	12	18	19	21	24	27	48	76	154	323

(*c*) LIGHT LOADING DISTRICTS

No. 8	C	6	9	13	20							
No. 6	All	6	9	13	18	24						
No. 4	do	6	9	13	18	22	25	40	80	137		
No. 2	do	6	9	13	18	18	20	30	59	98	208	
No. 1	do	6	9	13	18	18	20	28	52	85	178	380
No. 00	do	6	9	13	18	18	20	26	46	72	140	290
No. 0000	do	6	9	13	18	18	20	24	43	66	126	246

56629°—16——11

The following tables, 15 to 17, inclusive, give the normal and full load tensions in pounds in copper wires corresponding to the initial 60° F sags of Tables 12 to 14.

TABLE 15

Tensions in Hard and Medium Drawn Covered Copper Wires

(*a*) HEAVY LOADING DISTRICTS [8]

Size A. W. G.	Grades of construction	Conditions	Span lengths 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
No. 8	C	60° F, no load	63	65	64				
		0° F, loaded	467	520	558				
No. 6	A	60° F, no load	94	98	92				
		0° F, loaded	577	635	670				
	B	60° F, no load	112	122	115				
		0° F, loaded	604	682	718				
	C	60° F, no load	140	146	140	143			
		0° F, loaded	639	713	762	820			
No. 4	All	60° F, no load	205	214	205	209	205		
		0° F, loaded	817	899	948	1007	1040		
No. 2	do	60° F, no load	325	339	325	396	434	407	368
		0° F, loaded	1081	1160	1195	1364	1472	1524	1508
No. 1	do	60° F, no load	396	413	412	502	573	571	537
		0° F, loaded	1220	1314	1365	1555	1710	1708	1839
No. 00	do	60° F, no load	630	656	679	830	973	1021	1032
		0° F, loaded	1713	1796	1860	2130	2370	2545	2635
No. 0000	do	60° F, no load	961	1002	1092	1311	1537	1889	2065
		0° F, loaded	2430	2490	2620	2970	3310	3850	4220

(*b*) MEDIUM LOADING DISTRICTS [9]

Size A. W. G.	Grades of construction	Conditions	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
No. 8	C	60° F, no load	75	80	77				
		15° F, loaded	368	412	438				
No. 6	A	60° F, no load	112	119	115				
		15° F, loaded	457	509	534				
No. 6	B	60° F, no load	140	145	140	142			
		15° F, loaded	490	541	575	612			
No. 6	C	60° F, no load	169	175	172	172			
		15° F, loaded	517	571	614	653			
No. 4	All	60° F, no load	247	256	252	221	253		
		15° F, loaded	671	730	769	800	850		
No. 2	do	60° F, no load	392	406	399	443	489	489	453
		15° F, loaded	909	953	998	1090	1183	1250	1267
No. 1	do	60° F, no load	476	494	485	593	651	762	790
		15° F, loaded	999	1107	1126	1279	1400	1590	1629
No. 00	do	60° F, no load	758	795	772	1029	1155	1416	1413
		15° F, loaded	1501	1549	1528	1843	2042	2364	2457
No. 0000	do	60° F, no load	1159	1440	1180	1529	1920	2485	2581
		15° F, loaded	2181	2358	2122	2590	3080	3740	387

[8] Corresponds to the initial 60° F sags of Table 12*a*.
[9] Correspondst o the initial 60° F sags of Table 12*b*.

TABLE 15—Continued

(*c*) LIGHT LOADING DISTRICTS [10]

Size A. W. G.	Grades of construction	Conditions	Span lengths 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
No. 8	C	60° F, no load	94	99	94	95	......	......	......
		30° F, loaded	295	328	350	373	......	......	......
No. 6	A	60° F, no load	140	145	140	142	......	......	......
		30° F, loaded	374	407	428	453	......	......	......
	B	60° F, no load	169	175	172	172	176	......	......
		30° F, loaded	402	439	466	492	523	......	......
	C	60° F, no load	209	220	210	215	211	......	......
		30° F, loaded	433	476	501	534	560	......	......
No. 4	All	60° F, no load	306	321	306	314	309	......	......
		30° F, loaded	574	620	639	676	695	......	......
No. 2	do.	60° F, no load	486	509	488	542	596	715	676
		30° F, loaded	797	852	852	928	1050	1171	1180
No. 1	do.	60° F, no load	590	618	593	691	790	955	958
		30° F, loaded	940	986	980	1103	1226	1425	1470
No. 00	do.	60° F, no load	939	984	933	1158	1373	1303	1827
		30° F, loaded	1390	1433	1365	1617	1860	1928	2362
No. 0000	do.	60° F, no load	1434	1500	1440	1862	2205	2895	3255
		30° F, loaded	2108	2166	2022	2550	2920	3652	4034

[10] Corresponds to the initial 60° F sags of Table 12*c*.

TABLE 16

Tensions in Soft Drawn Covered Copper Wires

(*a*) HEAVY LOADING DISTRICTS [11]

Size A. W. G.	Grades of construction	Conditions	Span lengths 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
No. 6	C	60° F, no load	80	83	80	......	......	......
		0° F, loaded	546	594	614	......	......	......
No. 4	A	60° F, no load	117	121	117	......	......	......
		0° F, loaded	670	712	727	......	......	......
	B and C	60° F, no load	137	143	139	......	......	......
		0° F, loaded	712	778	800	......	......	......
No. 2	A	60° F, no load	217	226	220	253	......	......
		0° F, loaded	906	958	968	1088	......	......
	B and C	60° F, no load	261	277	267	267	262	......
		0° F, loaded	980	1065	1092	1124	1135	......
No. 1	A	60° F, no load	317	337	325	325	319	......
		0° F, loaded	1110	1195	1202	1228	1235	......
	B and C	60° F, no load	396	413	396	394	396	......
		0° F, loaded	1221	1314	1346	1386	1424	......
No. 00	All	60° F, no load	630	656	700	696	719	......
		0° F, loaded	1711	1795	1869	1920	1974	......
No. 0000	do.	60° F, no load	960	1000	1114	1177	1280	......
		0° F, loaded	2432	2490	2640	2755	2955	......

[11] Corresponds to the initial 60° F sags of Table 13*a*.

TABLE 16—Continued

(*b*) MEDIUM LOADING DISTRICTS [12]

Size A. W. G.	Grades of construction	Conditions	Span lengths					
			100 feet	125 feet	150 feet	175 feet	200 feet	250 feet
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
No. 6	C	60° F, no load	94	97	95	......	......	......
		15° F, loaded	428	470	488	......	......	......
No. 4	All	60° F, no load	164	175	168	158	......	......
		15° F, loaded	572	626	646	643	......	......
No. 2	do	60° F, no load	325	338	326	333	325	......
		15° F, loaded	828	881	896	928	943	......
No. 1	do	60° F, no load	395	410	428	441	452	495
		15° F, loaded	953	999	1045	1090	1130	1239
No. 00	do	60° F, no load	630	653	708	769	837	984
		15° F, loaded	1322	1354	1439	1533	1639	1870
No. 0000	do	60° F, no load	960	996	1084	1178	1281	1499
		15° F, loaded	1876	1869	1975	2075	2216	2508

(*c*) LIGHT LOADING DISTRICTS [13]

Size A. W. G.	Grades of construction	Conditions	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet
No. 6	A	60° F, no load	94	97	95	......	......	......
		30° F, loaded	313	340	348	......	......	......
No. 6	B and C	60° F, no load	112	119	115	......	......	......
		30° F, loaded	342	375	389	......	......	......
No. 4	All	60° F, no load	205	215	222	236	234	......
		30° F, loaded	476	512	544	587	603	......
No. 2	do	60° F, no load	391	406	418	444	434	509
		30° F, loaded	705	742	771	823	828	953
No. 1	do	60° F, no load	477	493	532	583	633	706
		30° F, loaded	762	850	906	975	1050	1169
No. 00	do	60° F, no load	758	785	843	921	1006	1122
		30° F, loaded	1177	1181	1240	1334	1429	1555
No. 0000	do	60° F, no load	1159	1199	1291	1408	1535	1719
		30° F, loaded	1769	1769	1836	1968	2118	2300

[12] Corresponds to the initial 60° F sags of Table 13*b*.
[13] Corresponds to the initial 60° F sags of Table 13*c*.

TABLE 17

Tensions in Hard and Medium Drawn Bare Copper Wire

(*a*) HEAVY LOADING DISTRICTS [14]

Size A. W. G.	Grades of construction	Conditions	Span lengths—										
			100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet	400 feet	500 feet	700 feet	1000 feet
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
No. 8	C	60° F, no load	63	65	63	.....	.....	.....	.....	.....	.....	.....	.....
		0° F, loaded	423	474	510	.....	.....	.....	.....	.....	.....	.....	.....
No. 6	A	60° F, no load	99	103	99	.....	.....	.....	.....	.....	.....	.....	.....
		0° F, loaded	565	628	674	.....	.....	.....	.....	.....	.....	.....	.....
	B	60° F, no load	119	124	122	.....	.....	.....	.....	.....	.....	.....	.....
		0° F, loaded	588	652	709	.....	.....	.....	.....	.....	.....	.....	.....
	C	60° F, no load	119	124	122	110	.....	.....	.....	.....	.....	.....	.....
		0° F, loaded	588	652	709	740	.....	.....	.....	.....	.....	.....	.....

[14] Corresponds to the initial 60° F sags of Table 14*a*.

TABLE 17—Continued

(*a*) HEAVY LOADING DISTRICTS—Continued

Size A. W. G.	Grades of construction	Conditions	Span lengths										
			100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet	400 feet	500 feet	700 feet	1000 feet
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
No. 4	All	60 F, no load	187	197	202	208	200	168	149	.....	.....	.....	.....
		0° F, loaded	761	832	898	965	1000	1003	994	.....	.....	.....	.....
No. 2	do	60° F, no load	305	316	379	444	505	430	402	354	338	.....	.....
		0° F, loaded	1018	1094	1234	1365	1489	1525	1572	1590	1609	.....	.....
No. 1	do	60° F, no load	382	396	468	554	632	597	580	509	471	.....	.....
		0° F, loaded	1201	1264	1421	1580	1720	1805	1884	1898	1904	.....	.....
No. 00	do	60° F, no load	610	634	756	881	1010	1050	1092	955	909	.....	.....
		0° F, loaded	1696	1764	1970	2170	2366	2540	2900	2670	2670	.....	.....
No. 0000	do	60° F, no load	966	1002	1200	1403	1602	1868	2050	1835	1835	.....	.....
		0° F, loaded	2472	2509	2810	3110	3390	3770	4080	3980	4100	.....	.....

(*b*) MEDIUM LOADING DISTRICTS[15]

Size A. W. G.	Grades of construction	Conditions	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet	400 feet	500 feet	700 feet	1000 feet
No. 8	C	60° F, no load	93	98	94	.....	.....	.....	.....	.....	.....	.....	.....
		15° F, loaded	349	390	422	.....	.....	.....	.....	.....	.....	.....	.....
No. 6	All	60° F, no load	147	155	148	151	.....	.....	.....	.....	.....	.....	.....
		15° F, loaded	476	529	567	606	.....	.....	.....	.....	.....	.....	.....
No. 4	do	60° F, no load	235	247	237	242	236	281	246	216	.....	.....	.....
		15° F, loaded	633	692	726	772	804	925	932	945	.....	.....	.....
No. 2	do	60° F, no load	377	397	379	422	466	526	542	552	507	465	.....
		15° F, loaded	869	934	958	1030	1124	1264	1359	1477	1489	1483	.....
No. 1	do	60° F, no load	472	497	466	547	633	766	854	844	792	657	.....
		15° F, loaded	1034	1099	1109	1230	1354	1562	1719	1858	1890	1805	.....
No. 00	do	60° F, no load	753	789	757	932	1104	1408	1661	1760	1418	1549	1480
		15° F, loaded	1510	1575	1543	1900	2000	2370	2690	2920	2645	2957	2998
No. 0000	do	60° F, no load	1195	1261	1203	1560	1840	2510	3200	3210	3180	3070	3000
		15° F, loaded	2260	2320	2220	2670	3000	3760	4490	4580	4630	4650	4680

(*c*) LIGHT LOADING DISTRICTS[16]

Size A. W. G.	Grades of construction	Conditions	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet	400 feet	500 feet	700 feet	1000 feet
No. 8	C	60° F, no load	125	130	129	115	.....	.....	.....	.....	.....	.....	.....
		30° F, loaded	291	323	350	363	.....	.....	.....	.....	.....	.....	.....
No. 6	All	60° F, no load	198	206	202	203	198	.....	.....	.....	.....	.....	.....
		30° F, loaded	408	447	495	509	532	.....	.....	.....	.....	.....	.....
No. 4	do	60° F, no load	315	328	325	315	345	476	424	378	346	.....	.....
		30° F, loaded	563	605	635	663	708	873	883	929	932	.....	.....
No. 2	do	60° F, no load	505	526	521	518	674	943	864	823	773	715	.....
		30° F, loaded	810	856	874	898	1067	1354	1332	1389	1415	1447	.....
No. 1	do	60° F, no load	632	659	653	649	845	1182	1224	1164	1109	1046	1008
		30° F, loaded	982	1027	1040	1060	1267	1621	1704	1733	1759	1791	1850
No. 00	do	60° F, no load	1007	1050	1040	1033	1344	1880	2087	2110	2104	2110	2087
		30° F, loaded	1486	1533	1517	1512	1853	2412	2635	2710	2740	2813	2854
No. 0000	do	60° F, no load	1600	1670	1650	1650	2140	3000	3600	3600	3650	3740	3920
		30° F, loaded	2320	2360	2340	2320	2860	3760	4380	4410	4470	4580	4820

[15] Corresponds to the initial 60° F sags of Table 14*b*.
[16] Corresponds to the initial 60° F sags of Table 14*c*.

The following tables, 18 to 20, inclusive, give the normal and full load stresses in pounds per square inch in copper wires corresponding to the initial 60° F sags of Tables 12 to 14:

TABLE 18

Stresses in Hard and Medium Drawn Covered Copper Wires

(*a*) HEAVY LOADING DISTRICTS [17]

Size A.W.G.	Grade of construction	Condition	Span lengths 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
			lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²
No. 8	C	60° F, no load	4 820	5 030	4 890				
		0° F, loaded	35 900	40 000	42 800				
No. 6	A	60° F, no load	4 540	4 740	4 620				
		0° F, loaded	28 000	30 800	32 500				
	B	60° F, no load	5 450	5 930	5 580				
		0° F, loaded	29 300	33 100	34 800				
	C	60° F, no load	6 800	7 100	6 800	6 940			
		0° F, loaded	31 000	34 600	37 000	39 800			
No. 4	All	60° F, no load	6 260	6 530	6 260	6 375	6 260		
		0° F, loaded	24 900	27 400	28 900	30 700	31 700		
No. 2	do	60° F, no load	6 250	6 520	6 250	7 260	8 340	7 820	7 070
		0° F, loaded	20 800	22 300	23 000	26 250	28 300	29 300	29 000
No. 1	do	60° F, no load	6 030	6 280	6 270	7 640	8 720	8 690	8 170
		0° F, loaded	18 600	20 000	20 800	23 700	26 050	26 000	28 000
No. 00	do	60° F, no load	5 990	6 240	6 470	7 900	9 260	9 730	9 830
		0° F, loaded	16 300	17 100	17 700	20 270	22 550	24 200	25 100
No. 0000	do	60° F, no load	5 780	6 030	6 580	7 890	9 260	11 370	12 430
		0° F, loaded	14 650	15 000	15 800	17 900	19 950	23 200	25 250

(*b*) MEDIUM LOADING DISTRICTS [18]

Size A.W.G.	Grade of construction	Condition	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
No. 8	C	60° F, no load	5 780	6 140	5 930				
		15° F, loaded	28 300	31 700	33 700				
No. 6	A	60° F, no load	5 440	5 780	5 590				
		15° F, loaded	22 200	24 700	25 900				
	B	60° F, no load	6 800	7 060	6 800	6 880			
		15° F, loaded	23 800	26 250	27 900	29 700			
	C	60° F, no load	8 190	8 500	8 340	8 330			
		15° F, loaded	25 100	27 700	29 800	31 700			
No. 4	All	60° F, no load	7 530	7 810	7 670	6 740	7 710		
		15° F, loaded	20 450	22 250	23 450	24 400	25 900		
No. 2	do	60° F, no load	7 510	7 790	7 660	8 510	9 390	9 380	8 900
		15° F, loaded	17 450	18 500	19 150	20 900	22 700	24 000	24 300
No. 1	do	60° F, no load	7 250	7 510	7 380	8 870	9 910	11 600	12 020
		15° F, loaded	15 200	16 850	17 150	19 450	21 300	24 200	24 800
No. 00	do	60° F, no load	7 220	7 480	7 350	9 510	11 000	13 490	13 460
		15° F, loaded	14 300	14 750	14 550	17 550	19 450	22 700	23 400
No. 0000	do	60° F, no load	6 970	8 670	7 110	9 210	11 560	14 990	15 560
		15° F, loaded	13 150	14 200	12 800	15 600	18 550	22 550	23 300

[17] Corresponds to the initial 60° F sags of Table 12*a*.
[18] Corresponds to the initial 60° F sags of Table 12*b*.

TABLE 18—Continued

(*c*) LIGHT LOADING DISTRICTS [19]

Size A.W.G.	Grade of construction	Condition	Span lengths 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
			lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²
No. 8	C	60° F, no load	7 220	7 500	7 220	7 310	....	....	....
		30° F, loaded	22 700	25 200	26 900	28 700	....	....	....
No. 6	A	60° F, no load	6 800	7 060	6 800	6 880	....	....	....
		30° F, loaded	18 150	19 850	20 800	22 000	....	....	....
	B	60° F, no load	8 190	8 500	8 340	8 330	8 620	....	....
		30° F, loaded	19 500	21 300	22 600	23 900	25 400	....	....
	C	60° F, no load	10 150	10 650	10 200	10 410	10 250	....	....
		30° F, loaded	21 000	23 100	24 300	25 900	27 200	....	....
No. 4	All	60° F, no load	9 340	9 780	9 330	9 580	9 430	....	....
		30° F, loaded	17 500	18 900	19 500	20 600	21 200	....	....
No. 2	do	60° F, no load	9 330	9 770	9 360	10 400	11 430	13 710	12 980
		30° F, loaded	15 300	16 350	16 300	17 800	19 500	22 500	22 650
No. 1	do	60° F, no load	8 990	9 410	9 020	10 520	12 020	14 540	14 600
		30° F, loaded	14 300	15 000	14 900	16 800	18 650	21 700	22 350
No. 00	do	60° F, no load	8 940	9 370	8 980	11 020	13 090	12 410	17 400
		30° F, loaded	13 250	13 650	13 000	15 400	17 700	18 350	22 500
No. 0000	do	60° F, no load	8 640	9 040	8 680	11 220	13 280	17 420	19 600
		30° F, loaded	12 700	13 050	12 300	15 350	17 600	22 000	24 300

[19] Corresponds to the initial 60° F sags of Table 12*c*.

TABLE 19

Stresses in Soft-Drawn Covered Copper Wires

(*a*) HEAVY LOADING DISTRICTS [20]

Size A. W. G.	Grade of construction	Condition	Span lengths 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet
			lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²
No. 6	C	60° F, no load	3 890	4 010	3 860	....	....	....
		0° F, loaded	26 500	28 800	29 800	....	....	....
No. 4	A	60° F, no load	3 580	3 690	3 560	....	....	....
		0° F, loaded	20 400	21 700	22 150	....	....	....
	B and C	60° F, no load	4 180	4 360	4 240	....	....	....
		0° F, loaded	21 700	23 700	24 400	....	....	....
No. 2	A	60° F, no load	4 170	4 350	4 230	4 865	....	....
		0° F, loaded	17 400	18 400	18 600	20 900	....	....
	B and C	60° F, no load	5 000	5 320	5 130	5 130	5 030	....
		0° F, loaded	18 800	20 450	21 000	21 600	21 800	....
No. 1	A	60° F, no load	4 825	5 130	4 950	4 950	4 850	....
		0° F, loaded	16 900	18 200	18 300	18 700	18 800	....
	B and C	60° F, no load	6 030	6 280	6 030	6000	6 030	....
		0° F, loaded	18 600	20 000	20 500	21 100	21 700	....
No. 00	All	60° F, no load	5 990	6 240	6 670	6 640	6 850	....
		0° F, loaded	16 300	17 100	17 800	18 300	18 800	....
No. 0000	do	60° F, no load	5 780	6 030	6 720	7 090	7 715	....
		0° F, loaded	14 650	15 000	15 900	16 600	17 800	....

[20] Corresponds to the initial 60° F sags of Table 13*a*.

TABLE 19—Continued

(*b*) MEDIUM LOADING DISTRICTS [21]

Size A. W. G.	Grades of construction	Conditions	Span lengths 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet
			lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²
No. 6	C	60° F, no load	4 540	4 730	4 610	....	....	....
		15° F, loaded	20 800	22 800	23 700	....	....	....
No. 4	All	60° F, no load	5 000	5 330	5 130	4 820	....	....
		15° F, loaded	17 450	19 100	19 700	19 600	....	....
No. 2	do	60° F, no load	6 240	6 480	6 250	6 380	6 240	....
		15° F, loaded	15 900	16 900	17 200	17 800	18 100	....
No. 1	do	60° F, no load	6 010	6 240	6 520	6 710	6 880	7 540
		15° F, loaded	14 500	15 200	15 900	16 600	17 200	18 850
No. 00	do	60° F, no load	5 990	6 210	6 740	7 330	7 970	9 360
		15° F, loaded	12 600	12 900	13 700	14 600	15 600	17 800
No. 0000	do	60° F, no load	5 780	6 000	6 530	7 090	7 720	9 030
		15° F, loaded	11 300	11 250	11 900	12 500	13 350	15 100

(*c*) LIGHT LOADING DISTRICTS [22]

Size A. W. G.	Grades of construction	Conditions	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet
No. 6	A	60° F, no load	4 540	4 730	4 610	....	....	....
		30° F, loaded	15 200	16 500	16 900	....	....	....
No. 6	B and C	60° F, no load	5 440	5 780	5 590	....	....	....
		30° F, loaded	16 600	18 200	18 900	....	....	....
No. 4	All	60° F, no load	6 260	6 500	6 760	7 200	7 150	....
		30° F, loaded	14 500	15 600	16 600	17 900	18 400	....
No. 2	do	60° F, no load	7 510	7 790	8 020	8 510	8 330	9 770
		30° F, loaded	13 550	14 250	14 800	15 800	15 900	18 300
No. 1	do	60° F, no load	7 250	7 510	8 100	8 870	9 640	10 760
		30° F, loaded	11 600	12 950	13 800	14 850	16 000	17 800
No. 00	do	60° F, no load	7 220	7 480	8 030	8 780	9 580	10 690
		30° F, loaded	11 200	11 250	11 800	12 700	13 600	14 800
No. 0000	do	60° F, no load	6 970	7 220	7 780	8 470	9 250	10 340
		30° F, loaded	10 650	10 650	11 050	11 850	12 750	13 850

[21] Corresponds to the initial 60° F sags of Table 13*b*.
[22] Corresponds to the initial 60° F sags of Table 13*c*.

TABLE 20

Stresses in Hard and Medium Drawn Bare Copper Wires

(a) HEAVY LOADING DISTRICTS[23]

Size A. W. G.	Grade of construction	Condition	Span lengths— 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet	400 feet	500 feet	700 feet	1000 feet
			lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²	lbs./in.²
No. 8	C	60° F, no load	4 820	5 020	4 820								
		0° F, loaded	32 500	36 400	39 200								
No. 6	A	60° F, no load	4 800	5 010	4 800								
		0° F, loaded	27 400	30 500	32 700								
	B	60° F, no load	5 790	6 000	5 900								
		0° F, loaded	28 500	31 600	34 400								
	C	60° F, no load	5 790	6 000	5 900	5 360							
		0° F, loaded	28 500	31 600	34 400	35 900							
No. 4	All	60° F, no load	5 800	6 010	6 170	6 330	6 090	5 120	4 540				
		0° F, loaded	23 200	25 350	27 400	29 400	30 500	30 600	30 300				
No. 2	do	60° F, no load	5 850	6 070	7 280	8 520	9 700	8 250	7 720	6 800	6 480		
		0° F, loaded	19 550	21 000	23 700	26 200	28 600	29 300	30 200	30 500	30 900		
No. 1	do	60° F, no load	5 820	6 030	7 120	8 440	9 630	9 080	8 830	7 750	7 170		
		0° F, loaded	18 300	19 250	21 650	24 050	26 200	27 500	28 700	28 900	29 000		
No. 00	do	60° F, no load	5 810	6 030	7 190	8 400	9 620	10 000	10 390	9 100	8 650		
		0° F, loaded	16 150	16 800	18 750	20 700	22 500	24 200	27 600	25 400	25 400		
No. 0000	do	60° F, no load	5 820	6 030	7 240	8 460	9 660	11 240	12 340	11 060	11 060		
		0° F, loaded	14 900	15 100	16 950	18 750	20 400	22 700	24 600	24 000	24 700		

[23] Corresponds to the initial 60° F sags of Table 14a.

TABLE 20—Continued

(b) MEDIUM LOADING DISTRICTS[24]

Size A. W. G.	Grade of construction	Condition	Span lengths— 100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet	400 feet	500 feet	700 feet	1000 feet
			lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}
No. 8	C	60° F, no load	7 180	7 550	7 220	....	....	....	....	....	....	....	....
		15° F, loaded	26 800	30 000	32 400	....	....	....	....	....	....	....	....
No. 6	All	60° F, no load	7 150	7 515	7 200	7 345	....	....	....	....	....	....	....
		15° F, loaded	23 100	25 700	27 500	29 400	....	....	....	....	....	....	....
No. 4	do	60° F, no load	7 170	7 545	7 230	7 375	7 210	8 560	7 520	6 610	....	....	....
		15° F, loaded	19 300	21 100	22 100	23 500	24 500	28 200	28 400	28 800	....	....	....
No. 2	do	60° F, no load	7 245	7 625	7290	8 100	8 950	10 100	10 400	10 610	9 750	8 930	....
		15° F, loaded	16 700	17 950	18 400	19 800	21 600	24 300	26 100	28 400	28 650	28 500	....
No. 1	do	60° F, no load	7 195	7 560	7 245	8 340	9 645	11 650	13 000	12 840	12 050	10 000	....
		15° F, loaded	15 750	16 750	16 900	18 750	20 650	23 800	26 200	28 300	28 800	27 500	....
No. 00	do	60° F, no load	7 170	7 518	7 210	8 870	10 530	13 415	15 830	16 750	13 500	14 750	14 100
		15° F, loaded	14 380	15 000	14 700	18 100	19 050	22 600	25 600	27 800	25 200	28 150	28 550
No. 0000	do	60° F, no load	7 200	7 595	7 245	9 400	11 100	15 150	19 240	19 330	19 150	18 510	18 060
		15° F, loaded	13 600	13 950	13 350	16 100	18 100	22 650	27 050	27 600	27 900	28 000	28 200

(c) LIGHT LOADING DISTRICTS [25]

No. 8	C	60° F, no load	9 620	10 030	9 940	8 850	....	....	....	....	....	....	....
		30° F, loaded	22 400	24 850	26 900	27 900	....	....	....	....	....	....	....
No. 6	All	60° F, no load	9 600	10 000	9 910	9 840	9 600	....	....	....	....	....	....
		30° F, loaded	19 800	21 750	24 050	24 600	25 800	....	....	....	....	....	....
No. 4	do	60° F, no load	9 600	10 000	9 910	9 840	10 520	14 500	12 930	11 540	10 560	....	....
		30° F, loaded	17 150	18 450	19 350	20 200	21 600	26 600	26 900	28 300	28 400	....	....
No. 2	do	60° F, no load	9 700	10 100	10 010	9 960	12 950	18 120	16 580	15 820	14 850	13 750	....
		30° F, loaded	15 550	16 450	16 800	17 250	20 500	26 000	25 600	26 700	27 200	27 800	....
No. 1	do	60° F, no load	9 630	10 040	9 960	9 900	12 860	18 000	18 640	17 760	16 900	15 950	15 330
		30° F, loaded	14 950	15 650	15 850	16 150	19 300	24 700	25 950	26 400	26 800	27 300	28 200
No. 00	do	60° F, no load	9 600	10 000	9 910	9 840	12 800	17 930	19 850	20 120	20 050	20 100	19 850
		30° F, loaded	14 150	14 600	14 450	14 400	17 650	23 000	25 100	25 800	26 100	26 800	27 200
No. 0000	do	60° F, no load	9 650	10 050	9 980	9 920	12 870	18 050	21 700	21 700	21 950	22 530	23 600
		30° F, loaded	14 000	14 300	14 100	13 950	17 200	22 650	26 400	26 550	25 900	27 600	29 000

[24] Corresponds to the initial 60° F sags of Table 14*b*.

[25] Corresponds to the initial 60° F sags of Table 14*c*.

MECHANICAL DATA FOR COPPER WIRE [26]

The following table contains data on the ultimate strength and per cent of elongation before failure of hard, medium, and soft copper wire as given in the 1915 report of the A. S. T. M.

The elastic limit as given by the same society is 55 to 60 per cent of the ultimate strength for hard-drawn copper and 50 to 55 per cent for medium-drawn copper. There is no definite elastic limit for soft copper, but its behavior, after having a slight preliminary stretch, may be considered as approximately that of an elastic material having a limit of elasticity of 10 000 to 15 000 pounds per square inch.

The modulus of elasticity has been taken at 16 000 000 for all grades of copper.

TABLE 21

Mechanical Data for Copper Wire

Size A. W. G.	Diameter	Hard drawn		Medium drawn			Soft drawn	
		Average ultimate tension	Average elongation	Average minimum ultimate	Average maximum ultimate	Elongation	Avera ultimate tension	Average elongation
	Inches	Pounds	Per cent	Pounds	Pounds	Per cent	Pounds	Per cent
No. 8	0. 128	63 700	1. 06	49 660	56 660	1. 08		
No. 6	. 162	62 100	1. 14	49 000	56 000	1. 15		
No. 4	. 204	60 100	1. 24	48 330	55 330	1. 25	37 000	30
No. 2	. 258	57 600	1. 98	47 000	54 000	2. 50		
No. 1	. 289	56 100	2. 17	46 000	53 000	2. 75		
No. 0	. 325	54 500	2. 40	45 000	52 000	3. 00		
No. 00	. 365	52 800	2. 80	44 000	51 000	3. 25	36 000	35
No. 000	. 41	51 000	3. 25	43 000	50 000	3. 60		
No. 0000	. 46	49 000	3. 75	42 000	49 000	3. 75		

RESULTANT CONDUCTOR LOADINGS

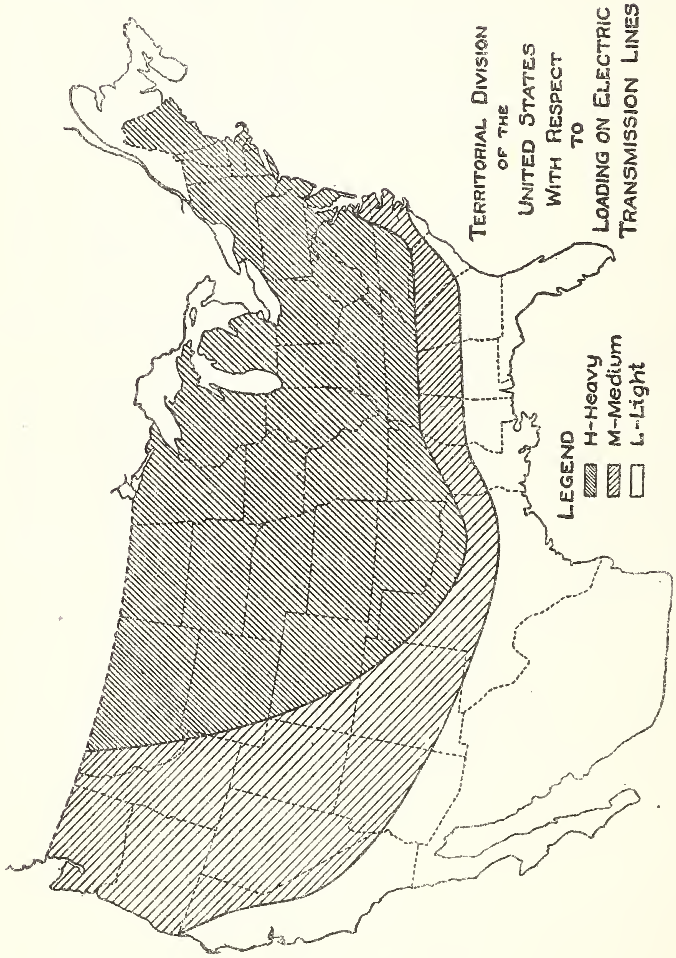
The following table gives the resultant loading in pounds per 100 feet for conductors of various sizes and materials in regions of heavy, medium, and light loading. The calculations are based on the assumed loadings given in rule 222 and on average values of the diameters of weather-proof wires. The over-all diameters of covered wires supplied by different manufacturers vary considerably and hence average values are chosen.

[26] A full discussion of the properties of conductors of various materials will be given in a later Bureau publication.

TABLE 22

Size A. W. G.	Diameter in inches over all	Weight of conductor in pounds per 100 feet	Resultant loading in pounds per 100 feet: Heavy loading	Medium loading = 2/3 heavy	Light loading = 4/9 heavy
Bare solid copper:					
No. 8	0.128	5.0	77.2	51.5	34.4
No. 6	.162	7.9	91.7	61.1	40.7
No. 4	.204	12.6	98.1	65.5	43.5
No. 2	.258	20.1	107.5	71.7	47.7
No. 1	.289	25.3	113.7	75.7	50.5
No. 00	.365	40.3	130.9	87.3	58.2
No. 0000	.460	64.1	157.5	105.0	[a] 80.1
T. B. W. P. solid copper:					
No. 8	.26	7.5	100.3	67.0	44.7
No. 6	.32	11.2	107.5	71.7	47.8
No. 4	.38	16.4	116.4	77.7	51.8
No. 2	.44	26.0	127.8	85.8	56.7
No. 1	.47	31.6	134.5	89.7	59.7
No. 00	.53	50.2	153.2	102.2	68.2
No. 0000	.65	76.7	185.0	123.5	[a] 96.0
T. B. W. P. stranded copper:					
No. 2	.444	27.0	128.5	85.5	57.2
No. 1	.518	32.8	139.5	92.8	62.0
No. 00	.662	52.2	166.6	111.0	74.0
No. 0000	.785	80.0	199.3	133.0	[a] 100.0
250 000 cir. mils	.862	98.5	221.7	147.5	[a] 123.0
350 000 cir. mils	.978	134.5	261.9	174.2	[a] 168.0
500 000 cir. mils	1.108	189.4	321.7	[a] 237.0	[a] 237.0
750 000 cir. mils	1.343	282.2	427.2	[a] 353.0	[a] 353.0
1 000 000 cir. mils	1.531	367.4	523.0	[a] 459.0	[a] 459.0
Bare stranded aluminum:					
No. 2	.291	6.1	102.3	68.2	45.5
No. 1	.328	7.7	106.5	71.0	47.4
No. 00	.414	12.2	116.8	78.0	51.8
No. 0000	.522	19.5	131.2	87.5	58.4

[a] These values are 25 per cent greater than the weight of the conductor. (See rule 222 a-2 and 222 a-3.)



District loading map

Appendix B.—LOADING DATA, MECHANICAL CHARACTERISTICS, AND RECOMMENDED TRANSVERSE STRENGTH OF OVERHEAD LINE SUPPORTS

1. DATA FOR COMPUTING TRANSVERSE AND VERTICAL STRENGTH REQUIRED FOR LINE SUPPORTS

(*a*) Assumed Transverse Pressures and Vertical Loads on Conductors of Various Materials and Sizes.—The values of transverse loads computed from rule 230 for various combinations of hazard (A, B, or C) and of loading districts (H, M or L) are given in Table 23.

TABLE 23

Transverse Wind Pressures (Pounds per Conductor per 100 Feet)

Size A. W. G.	Diameter in inches over all	Heavy loading			Medium loading M=2/3 H			Light loading L=2/3 M=4/9 H		
		A H	B H	C H	A M	B M	C M	A L	B L	C L
Bare solid copper:										
No. 8	0.128	113	66	38	75	44	25.0	50.0	29.3	16.7
No. 6	.162	116	68	39	77	45	25.7	51.6	30.4	17.2
No. 4	.204	120	70	40	80	47	26.7	53.4	31.1	17.8
No. 2	.258	126	73	42	84	49	28.0	56.0	32.5	18.7
No. 1	.289	129	75	43	86	50	28.7	57.4	33.3	19.1
No. 00	.365	136	79	45	91	53	30.7	60.5	35.1	20.2
No. 0000	.460	146	85	49	97	57	32.3	65.0	37.8	21.7
T. B. W. P. solid copper:										
No. 8	.26	126	73	42	84	49	28.0	56.0	32.5	18.7
No. 6	.32	132	77	44	88	51	29.3	58.7	34.2	19.6
No. 4	.38	138	80	46	92	54	30.7	61.4	35.8	20.5
No. 2	.44	144	84	48	96	56	32.0	64.0	37.3	21.3
No. 1	.47	147	86	49	98	57	32.7	65.4	38.2	21.8
No. 00	.53	153	89	51	102	59	34.0	68.0	39.6	22.7
No. 0000	.65	165	96	55	110	64	36.7	73.4	42.7	24.5
T. B. W. P. stranded copper:										
No. 2	.444	144	84	48	96	56	32.0	64.0	37.3	21.3
No. 1	.518	152	88	51	101	59	33.7	67.4	39.3	22.5
No. 00	.662	166	97	55	111	65	36.9	73.8	43.2	24.6
No. 0000	.785	178	104	59	119	69	39.7	79.4	46.3	26.5
250 000 cir. mils	.862	186	108	62	124	72	41.4	82.8	48.2	27.6
350 000 cir. mils	.978	198	115	66	132	77	44.0	88.0	51.2	29.3
500 000 cir. mils	1.108	211	123	70	140	82	46.8	93.6	54.8	31.2
750 000 cir. mils	1.343	234	136	78	156	91	52.1	104.2	60.8	34.4
1 000 000 cir. mils	1.531	253	147	84	169	98	56.2	112.4	65.6	37.5
Bare stranded aluminum:										
No. 2	.291	129	75	43	86	50.2	28.7	57.4	33.5	19.1
No. 1	.328	133	78	44	89	51.7	29.3	59.1	34.5	19.5
No. 00	.414	141	82	47	94	54.8	31.3	63.0	36.6	20.9
No. 0000	.522	152	89	51	101	59.1	34.0	68.0	39.3	22.7

The over-all diameters of weatherproof wire supplied by different manufacturers vary considerably, and hence average values are chosen for the table.

The vertical loads on conductors, based on the assumptions of rule 232 *a* (1), are given in Table 24.

Values for transverse and vertical loadings for wires of other sizes and materials can be readily computed.

TABLE 24

Vertical Loads on Conductors

Size A. W. G.	Vertical weight in pounds per 100 feet		
	Heavy=conductor+0.5-inch ice	Medium=conductor+0.25-inch ice	Light=conductor only
Bare solid copper:			
No. 8	44.0	16.7	5.0
No. 6	49.1	20.7	7.9
No. 4	56.4	26.7	12.6
No. 2	67.3	36.0	20.1
No. 1	74.4	42.0	25.3
No. 00	94.0	59.4	40.3
No. 0000	123.8	86.1	64.1
T. B. W. P. solid copper:			
No. 8	54.7	23.4	7.5
No. 6	62.7	29.1	11.2
No. 4	69.8	35.3	16.4
No. 2	84.3	47.4	26.0
No. 1	90.9	53.5	31.6
No. 00	113.3	74.5	50.2
No. 0000	147.6	104.7	76.7
T. B. W. P. stranded copper:			
No. 2	85.5	48.6	27.0
No. 1	96.1	56.7	32.8
No. 00	124.5	80.6	52.2
No. 0000	159.9	112.2	80.0
250 000 cir. mils	183.2	133.1	98.5
350 000 cir. mils	226.4	172.8	134.5
500 000 cir. mils	289.4	231.6	189.4
750 000 cir. mils	397.7	331.8	282.2
1 000 000 cir. mils	495.0	423.1	367.4
Bare stranded aluminum:			
No. 2	53.3	22.9	6.1
No. 1	59.2	25.4	7.7
No. 00	69.1	32.8	12.2
No. 0000	83.1	43.6	19.5

(*b*) CALCULATION OF MOMENTS OF RESISTANCE OF POLES.[27]—The resisting moments of sound chestnut, western red cedar, cypress, and southern pine poles for varying ground line circumferences given in Table 25 are based on a maximum allowable fiber stress of 2500 pounds per square inch, which is one-half of the assumed ultimate strength.

[27] For the purposes of these rules the ground line section is regarded as the most stressed section.

The resisting moments of northern white cedar poles are based upon an allowable fiber stress of 1800 pounds per square inch, which is one-half of the assumed ultimate strength.

The following formula has been used in calculating the moments:

M=0.000 2638 f C^3=moment in pounds feet; where,
f=allowable fiber stress in pounds per square inch,
C=circumference of the pole at ground line in inches.

TABLE 25

Resisting Moments of Sound Chestnut, Western Red Cedar, Cypress, and Southern Pine Poles for Varying Ground-Line Circumferences, Based on a Maximum Allowable Fiber Stress of 2500 Pounds per Square Inch

Circumference at ground in inches	Resisting moments in pound-feet	Circumference at ground in inches	Resisting moments in pound-feet	Circumference at ground in inches	Resisting moments in pound-feet
24	9120	34	25 920	44	56 180
25	10 300	35	28 280	45	60 100
26	11 590	36	30 770	46	64 200
27	12 980	37	33 410	47	68 470
28	14 470	38	36 190	48	72 940
29	16 080	39	39 120	49	77 600
30	17 810	40	42 220	50	82 440
31	19 650	41	45 450	51	87 480
32	21 610	42	48 860	52	92 730
33	23 700	43	52 430	53	98 180

For northern white cedar poles of the same ground line circumferences, the moments are 72 per cent of the above values.

2. METHOD FOR DETERMINING SIZE OF WOOD POLE REQUIRED

Given the span length, the size, material, number, and height of conductors, the size of pole which will fulfill the requirements of rule 235 may be obtained by use of the following formula for any transverse strength requirement as determined by hazards involved and climatic conditions imposed:

Let P_1 to P_n = Transverse pressures in pounds per 100 feet of span for all conductors concerned. (By Table 23.)

h_1 to h_n = Respective elevations in feet of conductors subjected to pressure P_1 to P_n,

S = Span length in feet (or ½ the sum of the adjacent spans),

Also let:

P_0 = Pressure in pounds per square foot as given in rule 230 according to local conditions (A, B, or C and H, M, or L),

D = Estimated mean diameter of pole,

H = Height of pole, above ground,

Then the moment due to the pressure on the pole is $M_p = \frac{1}{2} P_o DH^2$ pound-feet, and the moment due to the pressure on the conductors is

$$M_c = \frac{S}{100} (P_1 h_1 + P_2 h_2 \; . \; . \; . \; . \; . \; + P_n h_n) \text{ pound-feet,}$$

and the total bending moment on pole is $M = M_p + M_c$.

A pole should then be selected having a length equal to H plus the depth set in the ground, and a ground line circumference giving by Table 25, a resistive moment equal to, or greater than, M as obtained from the above formula.

The pole, of material, grade, size, and height so obtained, will meet the requirements of rule 235.

3. ILLUSTRATION OF ALLOWABLE NUMBER OF WIRES ON A GIVEN POLE

(*a*) Assumptions on Which Tables 26 and 27 are Based.—In Table 26 it is assumed (1) that all wire positions are filled and that crossarms are 2 feet apart; (2) that poles are set 5.5 feet in the ground; (3) that 6-pin crossarms are used unless otherwise stated; (4) that the placing of wires is begun at the top arm (wires 6 inches below the top of poles) and continues to lower crossarms until limited by strength of pole or clearance of wires above ground to a minimum of 19 feet at the support. This is assumed to be the minimum allowable clearance at the support if 18 feet clearance is to be maintained at the center of the span. (See Table 1.) Frequently a less number of crossarms is necessary where larger sags make the difference in elevation between the support and the center of the span greater than 1 foot. (See sag Tables 12, 13, and 14, appendix A.)

(*b*) Use of Table 26.—The maximum number of wires which can be carried in compliance with these rules by sound chestnut, western red cedar, cypress, and southern pine poles of different ground-line circumferences and different spans for a 35-foot pole, is given in Table 26, according to the hazards involved (A, B, or C) and the loading districts considered (H, M, or L).

The table may also be used for poles of greater height by using the ground-line circumference, but reducing the allowable number of wires, in proportion to the increase in elevation of the point of application of the load.

No definite tapers are assumed in Table 26, the pole strength being based entirely upon their ground-line circumferences, assuming this to be the most stressed section.

(*c*) Use of Table 27.—In order to show the wire-carrying capacities of poles of given top diameters, Table 27 is appended.

In this table chestnut poles are assumed to have a uniform taper of 3 inches in circumference per 5 linear feet and western red cedar poles to have a uniform taper of 2 inches in circumference per 5 linear feet. All other assumptions are the same as for Table 26.

TABLE 26

Allowable Number of No. 4 Solid Copper T. B. W. P. Wires to be Carried by 35-Foot Sound Chestnut, Western Red Cedar, Cypress, and Southern Pine Poles Having Ground-Line Circumferences of from 32 to 48 Inches and under Various Hazards (A, B, or C) and Loadings (H, M, or L). (See foregoing explanatory note.)

Hazard and loading	Span in feet	Circumference of pole at ground line in inches								
		32	34	36	38	40	42	44	46	48
A H	100	(*)	5	7	8	10	11	13	16	18
	125		4	5	6	8	9	11	12	14
	150		4	5	6	6	8	9	10	12
	200		3	3	4	5	6	6	7	9
B H	100	9	11	13	15	18	22	26	30	36
	125	7	8	10	12	14	17	20	23	25
	150	6	7	8	10	12	14	16	19	22
	200	4	5	6	7	9	10	12	14	16
C H	100	16	20	25	30	36	[a] 42	[a] 48	[b] 56	[c] 63
	125	13	16	19	23	28	34	[a] 38	[a] 45	[b] 49
	150	11	13	16	19	23	27	32	36	[a] 42
	200	8	10	11	14	16	19	23	27	31
A M	100	(*)	9	11	13	16	18	22	26	30
	125		7	9	10	12	15	17	20	24
	150		6	7	9	10	12	13	16	19
	200		4	5	6	8	9	10	12	14
B M	100	14	17	21	25	30	36	[a] 40	[a] 48	[b] 54
	125	11	13	16	19	23	28	33	[a] 37	[a] 43
	150	9	11	13	16	19	22	26	31	36
	200	7	8	10	12	14	16	19	22	26
C M	100	26	33	[a] 39	[a] 48	[b] 55	[c] 63	[d] 72	[d] 72	[d] 72
	125	21	26	32	36	[a] 44	[b] 50	[b] 60	[c] 68	[d] 72
	150	17	21	25	31	36	[a] 42	[a] 48	[b] 57	[c] 64
	200	12	15	17	21	26	32	36	[a] 42	[b] 49
A L	100	12	14	17	21	26	31	36	[a] 40	[a] 48
	125	9	11	13	17	20	23	28	33	36
	150	8	9	11	14	17	19	22	26	31
	200	6	7	8	10	12	14	16	19	22
B L	100	22	27	34	[a] 39	[a] 48	[b] 54	[c] 62	[d] 72	[d] 72
	125	17	21	26	32	36	[a] 43	[b] 49	[b] 58	[c] 65
	150	14	17	21	25	31	36	[a] 41	[a] 48	[b] 54
	200	10	13	15	18	22	26	31	36	[a] 41
C L	100	[a] 42	[b] 50	[b] 60	[d] 72	[d] 72	[d] 72	[d] 72	[d] 72	[d] 72
	125	34	[a] 40	[a] 48	[b] 57	[c] 67	[d] 72	[d] 72	[d] 72	[d] 72
	150	27	32	[a] 39	[a] 48	[b] 56	[c] 64	[d] 72	[d] 72	[d] 72
	200	19	24	29	36	[a] 41	[a] 48	[b] 55	[c] 62	[d] 72

* Blank spaces indicate that 35-foot poles can not be used with so small a ground-line circumference, since pole top would be less than 7 inches. (See rule 235 *e*.)

[a] These numbers of wires will require 8-pin crossarms.

[b] These numbers of wires will require 10-pin crossarms.

[c] These numbers of wires will require 12-pin crossarms.

[d] These numbers of wires will fill all available pole space when carried on 12-pin crossarms.

All others are carried by 6-pin crossarms.

TABLE 27

Allowable Number of No. 4 Solid Copper T. B. W. P. Wires to be Carried by 35-Foot Chestnut and Western Red Cedar Poles Having Top Diameters of 6, 7, 8, and 9 Inches and Tapers as Indicated in the Table. All other conditions are the same as for Table 26. (See foregoing explanatory note.) For poles of greater height the allowable number of wires will be determined from 3 b above and Table 26.

Hazard and loading	Span in feet	Chestnut—Taper=3 inches in circumference per 5 linear feet				Western red cedar—Taper=2 inches in circumference per 5 linear feet			
		6-inch top	7-inch top	8-inch top	9-inch top	6-inch top	7-inch top	8-inch top	9-inch top
A H	100	(*)	10	12	16	(*)	5	7	10
	125		8	10	12		4	6	8
	150		6	8	10		4	5	6
	200		5	6	8		3	4	5
B H	100	14	18	23	31	7	10	14	18
	125	11	14	18	23	6	8	11	14
	150	9	12	15	19	5	7	9	12
	200	7	9	11	14	4	5	7	9
C H	100	25	36	[a]45	[b]56	14	20	28	36
	125	21	27	36	[a]44	12	15	21	28
	150	17	23	29	36	9	13	17	23
	200	12	16	21	27	7	9	12	16
A M	100	(*)	15	20	26	(*)	9	12	16
	125		12	16	20		7	9	12
	150		10	13	16		6	8	10
	200		7	9	12		4	6	8
B M	100	22	29	[a]37	[a]48	12	16	22	30
	125	18	23	30	36	10	13	18	24
	150	14	18	24	31	8	11	14	19
	200	10	13	17	22	6	8	11	14
C M	100	[a]42	[b]54	[c]68	[d]72	23	34	[a]43	[b]56
	125	34	[a]43	[b]54	[c]67	18	25	35	[a]45
	150	27	36	[a]46	[b]56	14	20	28	36
	200	19	26	34	[a]41	11	15	20	27
A L	100	19	25	33	[a]40	10	14	20	26
	125	15	19	25	33	8	11	15	20
	150	12	16	20	27	7	9	12	16
	200	9	12	15	19	5	7	9	12
B L	100	36	[a]47	[b]59	[d]72	19	27	36	[a]48
	125	28	36	[a]48	[b]58	15	21	28	[a]37
	150	22	30	[a]37	[a]48	12	17	23	31
	200	16	21	28	36	9	12	17	22
C L	100	[c]64	[d]72	[d]72	[d]72	36	[a]48	[c]65	[d]72
	125	[b]50	[c]65	[d]72	[d]72	29	[a]39	[b]51	[c]67
	150	[a]42	[b]56	[c]69	[d]72	23	33	[a]43	[b]60
	200	29	[a]40	[b]50	[c]62	14	21	29	[a]41

* Blank spaces indicate that 6-inch poles can not be used. (See rule 235 *e*.)
[a] These numbers of wires will require 8-pin crossarms.
[b] These numbers of wires will require 10-pin crossarms.
[c] These numbers of wires will require 12-pin crossarms.
[d] These numbers of wires will fill all available pole space when carried on 12-pin crossarms.
All others are carried by 6-pin crossarms.

A taper of 3 inches in circumference per 5 linear feet, for chestnut, is approximately 1 inch in diameter per 5 linear feet, while a taper of 2 inches in circumference per 5 linear feet, for cedar, is approximately 1 inch in diameter per 8 linear feet. These tapers are very close to those assumed for the larger poles in generally accepted specifications.

The method of calculating Tables 26 and 27 is a process somewhat similar but reversed from that given in 2 above.

The maximum number of wires of other sizes or materials on poles of other fiber strengths may be readily computed from Tables 23 and 25.

DISCUSSION OF PART II—ELECTRICAL SUPPLY AND SIGNAL LINES

Sec. 20. GENERAL PROTECTIVE REQUIREMENTS

200. Scope of Rules

The rules for lines differ in essential respects from those for stations and for utilization equipment. The latter two sets are very similar in the general respects that conductors and equipment are confined to limited areas where persons are usually present, and that the safeguarding of these persons by actual enclosure of the current-carrying parts or by use of barriers or by the elevation of such parts beyond reach, is not only desirable, but generally feasible. With lines on the other hand, the conductors and equipment are not confined to limited areas, and with few exceptions are not under constant observation. Safeguarding by enclosure is feasible with underground lines, and in fact is almost essential to operation. For overhead lines, however, isolation by elevation must be generally depended upon for the safety of persons in the vicinity. This isolation 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 be unimpeded.

Practice and experience have determined reasonable limits for elevation of lines and equipment, and for the strength of construction necessary to withstand conditions. 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.

201. Application of the Rules and Exemptions

The rules are intended to be observed completely in new work under ordinary conditions. Alternatives are presented and conditioned on the practicability of enforcement so that no hardship should result from intelligent administration. The rules are intended to be observed also in extensions or reconstructions where practicable.

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 proportions, 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.

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 attendants 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 for other reasons than accident prevention, to comply fully with the rules. The replacement on a single pole of the crossarms so as to have the supply lines above signal lines, 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.

202. 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 concerned, and other determining conditions. In cities and congested areas, where the population is relatively dense and the hazard from unsubstantial or exposed construction is correspondingly great, the greater business will, of course, support safer and more substantial construction than can be afforded or is needed in sparsely settled communities. The code has taken these differences in hazard carefully into account, and the requirements are much less for sparsely settled than for densely populated districts.

203. 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 will desire and some companies already provide. 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. As experience justifies it, some of the requirements may be strengthened in subsequent editions of the code.

205. Isolation, Guarding, and Accessibility

(*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 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 section 24).

(*b*) GUARDS AND WARNING SIGNS.—The best means of making overhead lines inaccessible, after thoroughly isolating them, is by making climbing difficult without the use of special means, such as ladders or spurs. If poles are not stepped close to the ground, they are usually sufficiently inaccessible, and the use of steps on the upper part of the pole may be desirable to prevent injury to the pole by spurs.

(*d*) 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 255).

208. Identification of Conductors and Poles

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.

Conductors and equipment should not be permitted to transfer indiscriminately from one pin or crossarm position to another. A fixed scheme of arrangement, whereby series-arc circuits, for example, would be maintained on certain pin positions of certain crossarms throughout a 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.

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 crossarm 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 crossarm carrying conductors operating in excess of a specified voltage, or a distinctive color for the crossarm itself, has proven to be a useful identification.

It is equally 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.

Sec. 21. GRADES OF CONSTRUCTION REQUIRED FOR CROSSINGS AND OTHER CONDITIONS OF HAZARD

210. Required Grades of Overhead Line Construction, and Arrangement of Levels

(*a*) VARIOUS CONDITIONS OF HAZARD.—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 signal line or vice versa, by crossings of one supply system over another, and by crossings of supply or signal lines over a steam railway. In urban districts the hazard from fallen wires is of course greater than in rural districts. Superior construction should be provided where these special conditions exist to reduce their hazards as much as practicable.

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

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 supply circuits of equal nominal voltage. Under such conditions therefore the same grade of construction is called for. Where such circuits, however, expose signal lines by crossing above, conflicting with, or being located above and on the same poles with the signal lines, the hazards caused to the signal lines are very different from those of supply lines of equal voltage. The fusing of telephone protectors has been made heavy enough to prevent their blowing by contact of the signal circuits with constant-current circuits up to 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 injure subscribers. 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 usually sustain an arc and endanger both subscriber and property.

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 signal 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 great number of persons constantly exposed to fallen conductors calls for additional consideration. A fallen conductor in a location having a population of 1000 persons per square mile is obviously introducing a much greater hazard 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, is a far too prolific cause of accidents.

It is necessary to indicate certain grades of mechanical construction to reduce as far as possible the hazards outlined above. This is done in rules 211 to 219 inclusive and five different grades are listed, as required under different conditions of hazard. The required mechanical construction for these grades is specified in sections 22 and 23 for grades A, B, and C, and in rules 280 and 281 for grades D and E. The required construction is intended to provide adequate strength to withstand a certain assumed mechanical loading of the conductors and poles due to ice, wind, and temperature, according to the district concerned. The relative and actual strengths called for under different conditions have been found generally to accord with good engineering practice through the United States as reasonable strengths for the conditions and hazards involved. In general, the assumed loadings are very much smaller than those which the rules of European countries assume. The voltage gradations where affecting the required strength of construction closely follow those contained in the orders of some of the State commissions and have met wide approval among electrical engineers.

While some communities have seen fit to set fixed limits to the voltage carried by overhead lines within their territory 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.

(*b*) Arrangement of Relative Levels.—In general, lines of the higher voltage classifications should provide greater service reliability than lines of lower voltages, and they should therefore be maintained in a more secure condition mechanically. Also workmen are less frequently required to work upon the higher voltage lines. For these reasons it is advisable to place the highest voltage lines in the upper positions and the others in the order of their voltages below.

Where it is not practicable to carry the higher voltage line at the higher levels the construction of such lower voltage lines as are placed above those of a higher classification must be made as strong in general as is required for the higher voltage line, when they occupy the higher level in which they are normally maintained.

Sec. 22. LOADING ASSUMPTIONS AND SAGS OF CONDUCTORS

221. Conductors—Material and Minimum Sizes

(*a* and *b*) For discussion of some of the reasons leading to assignment of minimum conductor sizes, see rules 223, 240, and 241 and their discussions.

(*c*) 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 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, and sag tables under preparation will assign limits to allowable span lengths for this and larger sizes.

Even with steel reinforcement, aluminum is much lighter than equal sizes of copper and for the same sags would blow about more. A study is now under way to ascertain whether aluminum (reinforced) conductors of the same size may be strung safely at the same sags as hard or medium-drawn copper when the total strength, elastic limit, and range of sags are duly considered. This study will result in additional tables under Appendix A for aluminum (alone and reinforced).

(*d*) Service leads are usually strung to much greater sags than are line conductors, largely to relieve the poles of unbalanced side stresses. Owing to their small size, however, and the nature of the attachments at buildings such leads are quite frequently down in storms. Their usually low voltage and frequently short spans has made it appear inadvisable to require larger sizes than given in this rule or to specify sags closely for the shorter spans (see Appendix A for sags).

(*e*) Signal conductors are required to have grade A, B, or C sags only in a few cases, especially (1) where they are carried over high voltage supply lines or over trolley contact conductors and (2) where they are unprotected signal lines either for public use, or otherwise exposing other lines or traffic below them and themselves elsewhere exposed by high-voltage supply lines in a specified serious manner.

It is probable that the same minimum conductor sizes as required for supply conductors of the corresponding grades is a consistent requirement, and this is made except for grade C signal lines in short spans. The consensus of judgment of our conferees has been that it is reasonable in the shorter spans of grade C signal lines to permit a less conductor size than required for the supply lines whose degree of hazard they approximate. This variation for signal lines from the provisions of rule 223, however, presents the great difficulty that with these very small conductors, 12 to 9 gauge, it is impossible to string to large enough sag in spans of 100 to 150 feet to prevent greatly exceeding the yield point under load, since such sags would entail constant swinging together even in light winds. A smaller initial sag at 60° F has therefore been allowed, duly recognizing, however, that by this reduction the sag under full load is only slightly reduced and the variation of sag from no load to full load is greatly increased. Such lines therefore need greater clearances over other lines at 60° F than are specified for supply lines in rules 240 and 242 (see discussion under 223*d*), where carried above other conductors. The separations allowed for conductors by rule 241 are also insufficient for the full-loaded condition of such small conductors or even for comparatively small loads, since the sags will become so great under load and the conductors are so very light as to swing considerably. However, swinging together is ordinarily less harmful, not resulting usually in burn-offs as with supply conductors, but merely in bad service on the signal lines, which this code does not necessarily rule upon.

222. Loads Assumed in Determining Stresses in Conductors

The stress in conductors depends upon the pressure of the wind and the thickness of the ice coating, which may be carried by the wires and upon the changes in temperature which affect the conductor length and so change its stress where 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 temperatures 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.

Obviously different strength requirements are requisite in these districts. The rule makes three gradations of loading on which the sag tables of Appendix A are based. In a later publication will be given a further discussion of this subject with a list of communities which shows their classification with regard to the three grades of loading. The map in Appendix A indicates the boundaries of the regions of light, medium, and heavy loading, respectively.

223. Recommended Normal Sags

(*a* and *b*) The sags specified in this rule (and given in Appendix A) 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 on 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 (see also National Electric Light Association recommendations) 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, both from the standpoint of 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 stress; (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 crossarm, 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 13 for soft copper larger than No. 1 A. W. G.

In contrast to the present practice regarding sags in heavy conductors, investigation shows that except in short spans, it is frequently, though by no means generally, 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 wind storms. It is 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 14 for soft copper of No. 6 A. W. G.

The advantage in eliminating the smaller sizes is indicated by the experience of a typical eastern city whose minimum size of line conductor is No. 4 A. W. G. soft copper. Their sag values, as measured, are shown in figure 15 for No. 4 and No. 0 A. W. G. soft copper, indicating that in general the existing sags are much greater than the values recommended in these rules.

(*c*) Conductors of hard and medium drawn copper have mechanical characteristics which are much more satisfactory for line use than those of soft copper, the characteristics of which are hereafter discussed in some detail. 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.

The normal sags specified 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.

(*d*) 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 minimums by rules 241 and 242.

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 lines 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 24 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 240 *c* 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 two 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 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 separations will, by rule 242, become excessive and usually prohibitive.

(*e*) It is recommended by rule 223 *e* that medium copper be used for new overhead lines rather than soft copper, since 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 above 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. (See under *a* above.)

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, 6 or 4, with its low yield point, to prevent stretch and increase of sag under frequently recurring wind and ice loads. It has necessarily 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 repeated 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 many cases throughout the country, 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 our tests are shown, even where made with a blow torch, not to reduce the strength of the conductor to an important degree.

It should be noted that the rules as given are not recommended to be mandatory during the first year after publication. It is expected, from the expressions made to us and to many utilities by manufacturers of wire, that they will be able long before the end of this year to supply any quantity of the medium copper from stock. At present few or none of the manufacturers 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.

(*j*) The necessity for frequent adjustment of sag should not exist, as it endangers linemen and indicates a condition dangerous to the public.

General.—It may be noted also that the advantages in using the smallest allowable sizes of copper are frequently not so great as appears 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 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 regulation, 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 (see section 21).

Sec. 23. STRENGTH OF POLES, TOWERS, AND OTHER LINE SUPPORTS

231. Strength of Crossarms and Conductor Fastenings

Conductors for overhead lines may at some one temperature and loading of wind or ice or both exert balanced stresses on pins, crossarms, and poles in tangent sections of pole lines. At other temperatures and loadings the stresses 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 23 of Appendix B it is seen that transverse wind load is unlikely to break conductor fastenings, pins, or crossarms, even with heavy conductors in long spans. The vertical load at times becomes serious for small crossarms, 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 crossarm to the point of attachment of the tie wire. The crossarm 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.

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 1½ inches at the shank, length of shank 4¼ 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 1000 pounds in a conductor when applied at the side tie-wire groove of the insulators most generally used, giving a lever arm of 3½ 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 the pins.

The minimum crossarm 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 both vertically and parallel with the line 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 stress of 700 pounds on the end pin (which would 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 crossarms 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 crossarms or double cross arms are often advisable. Bracing is, of course, generally necessary to withstand unbalanced vertical stresses, as with oscillating conductors, men at work, or line equipment carried on the crossarms.

In ordinary tangent sections of lines away from crossings (for which see rule 214) it is not contemplated that pins or ties shall be required to withstand broken conductor stresses with the larger sizes of conductors. Up to a No. 4 hard drawn wire, however, the pin and tie will ordinarily withstand the stress 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 stresses are normally unbalanced and the tie must be able to withstand the full stress to which the conductor loading can subject it. Double ties to double pins, strain insulators with rope sockets, and similar special arrangements then become necessary for the larger conductors. For extra pole reinforcement at such points, see rule 266.

234 and 235. Required Strength of Line Supports.

A complete discussion and detailed computations of the strength of wood, steel, and reinforced concrete structures for use as overhead line supports will be given in a later bureau publication.

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 one-third or one-half of the initial strength before the strength has fallen to two-thirds or one-half that initially required. But where this margin of strength can not be provided, the maintenance of the pole up to nearly its initial strength is very necessary. Preservative treatment, butt reinforcement, or other methods may be used to maintain the pole to a higher percentage of its initial strength. By the rule where this maintenance can be made so good as to keep the pole to not less than 75 per cent of its initial strength, the latter may be made only one-third greater than the working load, if the pole is a so-called selected clear pole of at least 8-inch top diameter.

Data for computing transverse strength of line supports, the determination of the size of wood poles required, and illustrations of allowable number of wires on given poles, together with their tables, are given in Appendix B.

Sec. 24. CLEARANCES AND SEPARATIONS OF LINE CONDUCTORS

240. Clearances of Conductors and Wires at Crossings

(*a*) Clearances above Railways, Roadways, and Footways.—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, which when carried into the neighboring lower clearance communities may cause serious hazard. The greater cost and relative weakness resulting from increasing the height of overhead lines, should be considered in connection with the needs of the traffic, and minimum clearances should be established which are generally fair and reasonable from both standpoints. Such clearances will of course be more than those at which some lines would otherwise be run, and would be less than those which would be necessary for some vehicle loads of unusual height.

A consideration of practice the country over, and of accidents from insufficient clearance or from rash conduct of traffic, has led to the recommendation of the given clearances of Table 1. Railway freight cars will probably not much exceed a height of 15 feet and to permit standardization of clearances should be limited to some such height. 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 not subject to sagging, and partly because their number is limited and their locations can be readily learned by brakemen.

For wire clearances above highways, the traffic under consideration of course varies more in its clear height requirements, although usually roadway vehicles are much lower than freight cars. The higher vehicles which are to be considered are hay wagons, box loads, and moving vans. Elevations of such vehicles above ground exceeding 12 to 14 feet will be very rare and it is probably 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 standing or setting on the tops of such vehicles, such obstructions, 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 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 held responsible for entirely avoidable accidents.

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.

(*b*) Conductors and Wires Crossing Others.—The required clearances of conductors are based on a 100-foot length of span because conductors of 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 dangerously to reduce 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 clearance.

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, nor 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 at 60° F. are so increased with even moderate span lengths that were not the span length very closely restricted, as is done in rule 223, the minimum clearances given in Table 2 would need to be rapidly increased for the longer spans. (See rule 240 *c;* also rule 223 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 frequently 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, they have come into contact.

Also, in the case of messenger wires supporting telephone or other cables it is necessary that safe separation be provided from supply lines, 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 lines, the clearances must be greater than those specified in the table or signal linemen can not safely work out on the cable. The smaller size of signal conductors and the small initial sags permitted for grade C signal conductors by rule 221 *e* makes the increase of sag under ice load excessive, as compared with that of supply conductors, and requires in general larger clearances when signal lines cross above supply lines than where the relative levels are reversed.

(*c*) Increased Clearances for (*a*) and (*b*).—The greater clearances called for where spans exceed certain minimum lengths 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 sags is greater with small than with large conductors. But as the lighter conductors are limited, partly for this reason, to the shorter spans (see rule 223) the complexity which a variation of clearance with conductor size variation would cause, seems unwarranted by the slightly greater accuracy.

A few inches displacement of the free end of a suspension insulator toward a crossing span it supports might reduce clearances 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 toward a crossing of a suspension insulator is entirely probable in sleet or even windstorms.

242. Required Line Conductor Clearances and Separations at the Supports

The conductor separations called for probably provide sufficient space for workmen on poles and also to prevent swinging together, except for the smallest permissible conductor sizes, 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 223. 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 Tables 12, 13, and 14), are liable 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.

243. Lateral Working Space and Vertical Separation Between Conductors at Different Levels (on the Same Structure)

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 clearance, it sometimes happens that a utility seriously reduces this working space between crossarms. Such reduced clearances greatly increase the hazards. The workman 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 equally an aid to better and more rapid work, since the workman 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.

Illustrations of the intent of the rule are given in Figs. 1 to 6,[28] which must be considered merely as examples of construction. The vertical and horizontal clearances called for in the rules and illustrated in the figures are generally between conductors rather than between pins or crossarms. However, in cases where the crossarms 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.

Table 4 note (*c*), see Fig. 2.

(*f*) See Fig. 5. The arrangement of conductors shown in Case 4 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.

(*i*) See Fig. 6. While Table 4 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 Fig. 6, 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.

[28] Figs. 1 to 15, shown on pp. 210–217.

244. Conductors of Different Sags on the Same Supports

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 rule 223 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 requiring 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 only moderate. (See discussion of rule 223.)

245. Clearances of Conductors of One Line from Poles and Conductors of Another Line

If conductors of a conflicting 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. This is especially likely to be dangerous when the conductors 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. Less clearance than required by paragraph (*c*) for conductors crossing past the pole of a second pole line is partly justified by the fact that the climbing space on the pole of the second line in case of a conflict will be clear and all the conductors concerned will be running in the same direction as the conductors of the second line, so that workmen will not be confused. The greater clearance of paragraph (*c*) is necessary because the conductors concerned are run in a different direction from those on the pole concerned, so that the workman would need to take extra thought and precaution were they as near as the conductors on his own pole.

246. Clearances of Vertical and Lateral Conductors

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 side. Where poles are used in common by supply and signal conductors it is customary to designate the sidewalk side as the climbing side, leaving the street side clear for attachment of lamp leads. At some distance below the lowest crossarm, however, it is necessary to make the climbing space either on the crossarm side or the other, usually the latter.

Vertical or lateral conductors should generally be as far as practicable from the climbing space, and unless specially protected, verticals need to be placed at some distance from the pole center to permit the climber's arms to be placed around the pole. Laterals need usually not be spaced quite as far from the pole center as is necessary for verticals, but should be maintained generally on the side opposite the climbing space at the point, and at approximately the level of the crossarm, so as to leave the lateral working space as free as possible and make it unlikely that an arm or leg will be inadvertently brought in contact with the lateral, the crossarm acting in some degree as a guard. If on the climbing side (as necessary with some conductors on buckarm poles) they should generally be placed the full width of the lateral space away from the crossarm.

It is frequently desirable to install pole steps on certain poles, particularly those having vertical conductors carried up along or near the pole surface, and when this is done the verticals must be located at such distances from steps that they do not prevent good foothold, or bring the foot dangerously near poorly protected wires.

(*d*) Insulating conduit as a protection for vertical conductors near the pole surface 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 may become deteriorated by atmospheric conditions, so as to endanger a person coming accidentally in contact with the vertical in climbing or moving about the pole.

(*e*) Ground wires, grounded cable sheaths, and grounded guys should probably be kept entirely insulated from wood poles carrying supply conductors, where these poles are climbed when the conductors are alive. A limited number of tests have been made and others are in progress tending 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 ground 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 ground wire or grounded metal sheath of cable is analogous to the protection afforded a guy wire by the insulator required by rule 252. It seems preferable to continue this insulating conduit all the way down the pole, or to keep the ground wire spaced on suitable nonabsorptive dielectric supports away from the pole. The rule, however, had required this protection only far enough down from open supply lines so that workmen in contact with such lines are not liable to have their feet or spurs in direct contact with the ground wire or cable sheath.

(*d*), (*e*), and (*f*). See Fig. 7.

247. Clearances from Buildings

See Figs. 8 and 9. The efficiency of firemen is much reduced when hampered by the proximity of 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.

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 above 300 to ground, as by placing them near the eaves out of usual reach, or else they should be positively guarded.

248. Clearances from Bridges

The clearances given are designed to prevent contact of 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 up to 7500 volts) 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 240.

249. Climbing Space

Crossarms providing a 30-inch climbing space between the pole pins are a stock article. Such arms should be used to provide a reasonably safe space in which a workman may climb a pole. This space should not be obstructed with lateral conductors, but a rectangular space not less than 30 inches on a side, horizontally, should be maintained. For voltages above 7500 and at lower voltages, if practicable, this space should be increased to avoid necessity for workmen either to crowd against conductors or to place temporary shields on them. Great effort should be made to maintain this same liberal climbing space on buck-arm poles, and this will require omitting use of one pin on each arm adjacent to the climbing space, if pins are, as is usual, spaced only 15 inches from pole centers. In those instances where poles are not climbed while the lines 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. (See Figs. 1, 3, 4, and 5.)

This rule as given permits the climbing space to move from side to side to allow of lines being carried past the pole and near its surface, instead of 15 or 18 inches away. This must usually be considered as undesirable practice and where attachment of lines close to the pole seems advisable, they should generally be on one side of the pole only, and the climbing space should generally be carried vertically at the other side. The climbing space between any two wires is required, however, 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 therefore be done in steps not less than 4 feet apart.

Sec. 25. SUPPORTING STRUCTURES AND ATTACHMENTS

251. Guys and Anchors

Frequently anchors for guy wires are subject to severe electrolysis conditions 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 (see rules 252 and 246 *e*). Guy wires bearing on the same shims on a wooden pole should have strain insulators inserted or be separately insulated from the shims.

When it is necessary to give additional support to a pole by the use of a guy wire the lead of the guy wire (horizontal distance from pole to attachment of guy wire and anchor) should, where practicable, not be less than two-thirds the height above ground of the attachment of the guy wire to the pole, and the anchorage to which the guy wire is attached should be capable of withstanding the load to which it will be subjected. Sometimes a head guy wire may well be carried back to the next pole in line.

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. The utility permitting 3 feet of a 5-foot rod to extend above ground could economize by purchasing a shorter and lighter rod, for in general an anchor so installed will pull out of the soil under a much smaller load than is necessary to break either the rod or guy wire.

When lining up the pull of a guy wire 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 rods are designed for loads in tension and not in bending.

252. Insulating or Mechanical Guards for Guy and Span Wires

(*a*), (*b*), and (*c*) 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 also come directly in contact with this guy wire 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 (see rule 205 *c*), while for guys attached to wood poles supporting conductors operating at over 15 000 volts they are often inadvisable due to their unreliability. In the latter case the pole will probably not be frequently climbed while the conductors are alive, and if climbed as high as lower voltage conductors the guy wire which is required in urban districts to be specially grounded, may frequently be attached to the pole above the latter and possibly afford more protection against the higher voltage than it adds by bringing ground potential to the pole top. (See Figs. 10 and 11.)

(*g*) 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.

The insulating value of a wood pole, especially when damp, is not to be depended upon, since it is often necessary for workmen to come near 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.

253. Transformers, Regulators, Lightning Arresters, Switches, and Similar Equipment on Supply Lines

(*b*) 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 climbing space (usually 30 inches square) or in the lateral working space parallel to line crossarms a reasonable degree of safety appears to be secured.

(*c*) 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.

254. Insulators

Although there is not entire agreement among engineers and manufacturers upon the proper requirements for insulators as affecting the safety of line construction, it is thought desirable to include such electrical requirements, particularly where crossings are concerned, as will insure a degree of safety from falling wires comparable with the mechanical security required at such places of hazard.

The grounding of pins or crossarms on which insulators are installed presents an added danger of a flash over at such points with the possibility of conductors being injured or entirely burned off. As this should be an electrically strong, rather than weak point, it seems reasonable to require some additional insulation under these circumstances, but as to how much there seems to be very little, if any, information available. Fifty per cent has been selected as a reasonable requirement and has met with general approval.

No standard method or specifications for testing insulators have been generally agreed upon, but the requirements of (*d*), as stated, seem to be in keeping with good modern practice. It is hoped that the experience of a year's trial of the present code, together with the results of investigations which are now under way, will be of service in revising the present requirements.

The provisions of (*f*) are most important. The special mechanical features of crossing structures are frequently of such a nature as to invite flash overs at the insulators on such structures rather than on other portions of the line, and the conductors at these locations are therefore subjected to special hazard. It is of the greatest importance, therefore, that construction be of such a nature as to prevent the burning and consequent falling of conductors.

255. Branch Connections

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.

Sec. 26. CROSSINGS OF SUPPLY LINES WITH RAILWAYS AND WITH SIGNAL LINES

266. Special Longitudinal Strength Requirements for Crossing Sections of Grades A and B Construction in Lines of a Lower Grade of Construction (or adjacent to Angles or Dead Ends)

Where a crossing span is in a tangent line of the same construction (grade A, B, or C) as is required for the crossing, there exists little reason for requiring pole structures to have special strength longitudinally at the crossing nor special rigidity. Failure of a crossing support by stresses in the direction of the line, or deflection toward the crossing sufficient to seriously reduce crossing clearances, can occur only by reason of greatly unbalanced conductor stresses in the direction of the line. These in turn can occur only by conductor breakage.

It is regarded as unnecessary to consider any excessive unbalancing of the conductor stresses where the line continues in the same direction and of the same strength, since such construction is presumed to be strong enough to withstand all the stresses to which it may be subjected, and the conductors are considered as unlikely to break or burn off.

At the ends of the strong construction, where weaker construction begins, however, as is the condition where a crossing of high-grade construction adjoins a line of low-grade construction, the conductor stresses on the terminal high-grade supports may become unbalanced by breaking of poles or conductors in the adjoining weaker section. Where a crossing or other high-grade section adjoins an angle in the line, the conductor stresses are, even normally, unbalanced. In either case it is necessary to reinforce the crossover supports against either failure or reduced clearances.

In some cases the structure itself may be made strong and rigid enough, as with special steel towers. In many cases additional strength and rigidity must be supplied by head guying away from the crossing, as is often the case with wood poles. Where head guying for the crossing poles themselves is impracticable, the longitudinal stress may be transferred to poles farther back if in a straight line with the crossing.

Either at a crossing or at an end section of high-grade construction the unbalanced stresses 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 stresses 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 stress.

Usually the use of a crossing structure strong enough to withstand the stresses or the transferring of this stress to a sufficiently strong and rigid end structure will be found more satisfactory than attempting a distribution of stress over two or more structures each of which alone is too weak for the load imposed. Often the computation of the division of stresses 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.

269. Special Short Span Crossing Construction. **(See Fig. 12)**

Sec. 27. OVERHEAD SUPPLY LINES (OR SIGNAL LINES WHICH HAVE TAKEN ON THE CHARACTER OF SUPPLY LINES) IN VARIOUS SITUATIONS

270. Separation of Pole Lines to Avoid Conflict

(*a*) Where supply and signal conductors must be placed on the same side of a street or highway and the voltage of the supply conductors permits, poles should preferably be used in common by all conductors concerned. Frequently, of course, it will be found both desirable and feasible to utilize another satisfactory route for one of the sets of lines concerned.

(*c*) On double-track construction it is often necessary to place supports for overhead trolley contact conductors relatively near to the tracks. Under such conditions passengers must of course be protected by screens or guards at windows and trainmen by suitable rules.

276. Electric Railway Feeders and Contact Conductors

(*b*) 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, that no part of the trolley contact wire or its current-carrying parts come closer than 12 feet to any generally accessible place.

(*c*) As voltages become greater the danger rapidly increases, and it seems entirely reasonable to require that where voltages over 1500 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.

Sec. 28. SIGNAL LINES AT CROSSINGS, CONFLICTS, AND COMMONLY USED POLES

280. Signal Lines Crossing Over Important Railways

One important difference between the detailed specification for signal-line crossings over railroads and the more general specification for supply lines in the various hazardous locations listed in section 21, is that the former specification always requires guys at the crossing poles. This permits the use of relative light poles in heavy signal lines. Guys are not required for poles of grade A, B, or C spans, even at crossings over railroads, unless the reduction of clearances by the deflection of an unguyed pole, or the lack of sufficient strength in the poles, actually requires their use.

For small numbers of line wires, the signal crossing structures are therefore frequently stronger when new than the loading of the district actually demands, undoubtedly a desirable condition. They are also very rigid, and this, together with the very hard copper used for telephone conductors generally, makes the serious reduction of clearances at signal-wire crossings improbable since the guyed poles can not readily deflect and the hard conductors can not elongate much without breaking. It is considered that a broken signal conductor of itself imposes no serious hazard, since it would usually fall clear of railroad signal wires, and imposes no voltage hazard on passers-by. Signal conductors at railroad crossings are therefore strung to small initial sags with the result that their mechanical stresses become very high in storms.

UNDERGROUND LINES

Sec. 29. MANHOLES, HANDHOLES, SPLICING CHAMBERS AND DUCTS, CONDUCTORS, AND EQUIPMENT

290. Location and Accessibility of Conduits and Manholes

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.

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.

292. Mechanical Details of Manholes

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.

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.

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.

293. Manhole Covers and Guards

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.

295. Installation of Conduits

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.

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.

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.

To arrest the action of an electric power arc and not to permit it to affect signal 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 signal 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.

296. Location and Identification of Conductors

Where practicable in underground construction supply and signal lines should, as with overhead construction, be given separate routes. In overhead lines a conflict or common use of poles, where a separate route is impracticable, causes some additional hazard which is met to a reasonable degree by compliance with the requirements of section 21 for specially strong construction in such conflicts and common use of poles.

In underground construction as with overhead construction, consideration of expense in providing separate routes for supply and signal lines or lack of room in a street where both utilities must be installed, may necessitate and justify the use of a single conduit line for both utilities. A somewhat greater hazard undoubtedly exists than with separate conduit lines, but undoubtedly less hazard than with overhead construction in general, since hazard is practically confined to employees and the public is rarely endangered by underground lines.

In some cases also an existing underground conduit system for supply lines may at least temporarily provide room for signal lines which it would otherwise not be practicable to place underground on account of expense. The reverse situation is even more likely to occur. It is usually desirable to use underground rather than overhead construction in communities where the consumption of energy is large enough so that the expense is warranted, recognizing, of course,that there are many communities where the density of the load is such that the expense of underground construction is not now warranted and may not be warranted for a long time to come.

Only where it is shown to the satisfaction of the administrative authority that conditions and considerations of expense fully warrant the temporary or permanent use of a single conduit line by both supply lines and signal lines for public use, should this less desirable joint use be permitted. 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 service alike.

297. Mechanical Protection, Support, and Guarding of Live Parts

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.

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 bushings or gaskets to insure water-tight joints.

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, conductors, and 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.

299. Multiple Connections

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 since different groups of workmen are usually involved on the two classes of construction.

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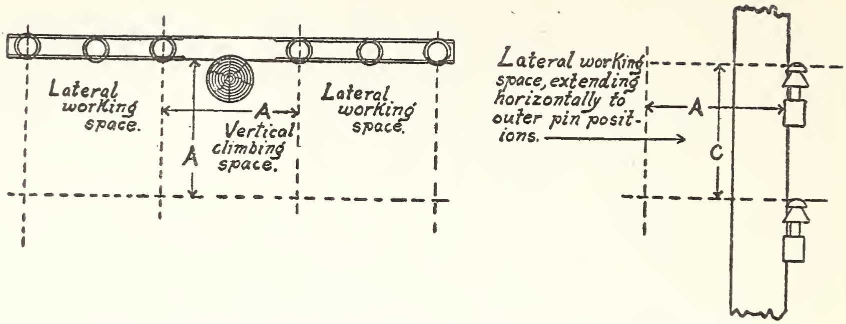

FIG. 1.—(*Rule 243*) *Lateral working space;* (*Rule 249*) *Climbing space*

A=to be not less than 30 inches when supply lines are above 300 volts and not less than 24 inches when all supply lines are below 300 volts.
C=to be not less than values given in Table 4, with a minimum of 2 feet.

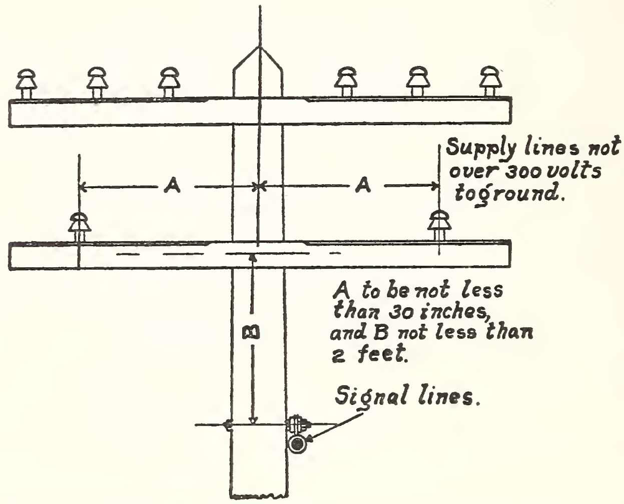

FIG. 2.—(*Rule 243; note C to Table 4*) *Supply lines over signal line cables*

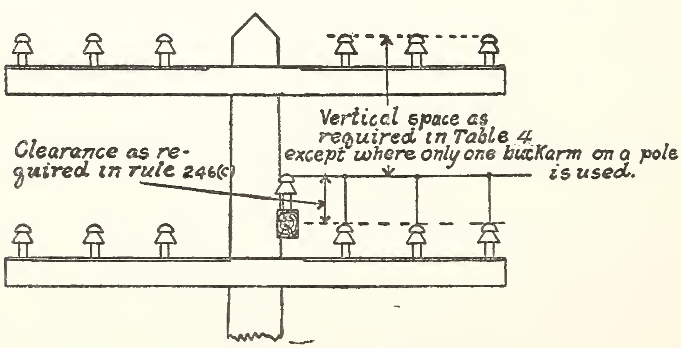

FIG. 3.—(*Rule 243 d*) *Obstruction to climbing and working space by buck arm*

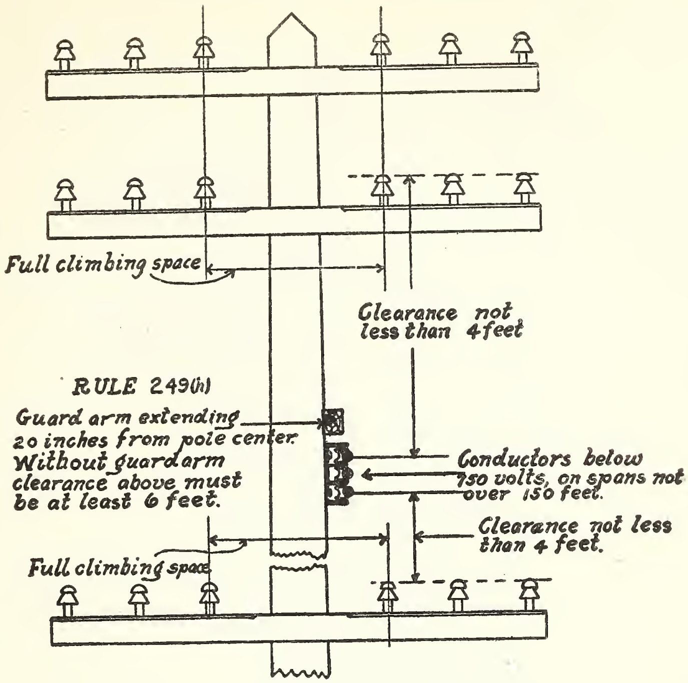

FIG. 4.—*Clearance for conductors on vertical racks*

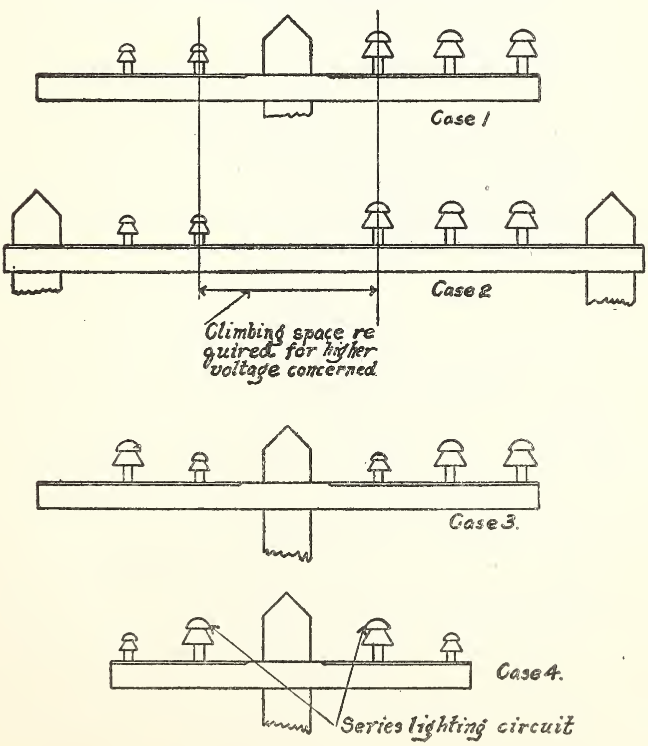

FIG. 5.—*(Rule 243 f) Permissible arrangements of supply lines of different consecutive voltage classifications on the same crossarm*

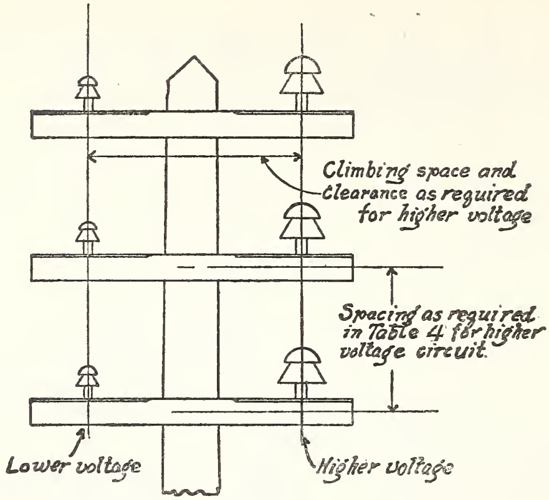

FIG. 6.—(*Rule 243 i*) *Circuits arranged vertically*

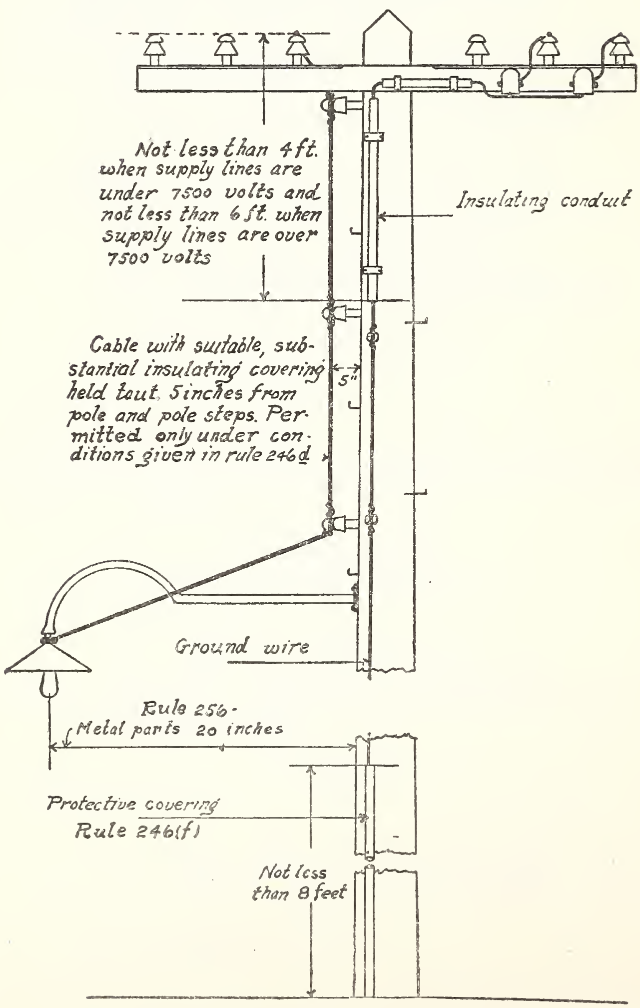

FIG. 7.—(*Rule 246 d and 246 e*) *Protection to vertical and lateral conductors*

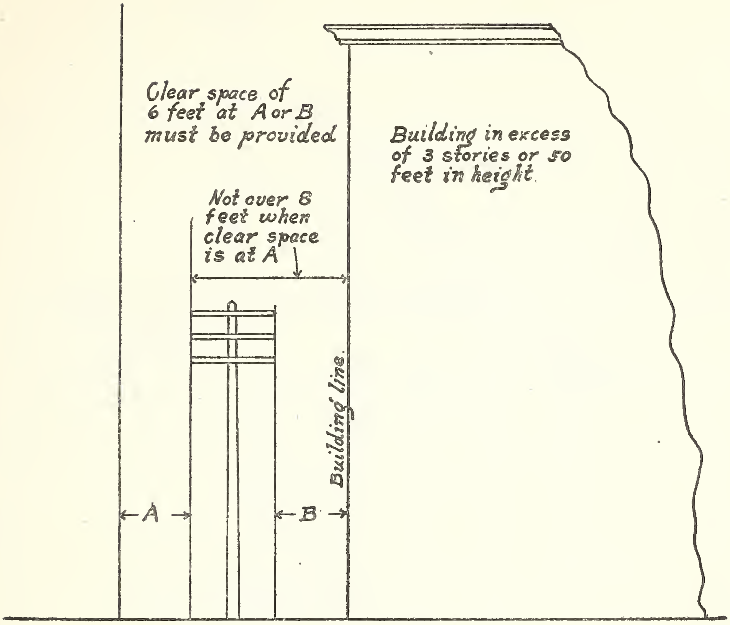

FIG. 8.—(*Rule 247 b*) *Space for fire ladders*

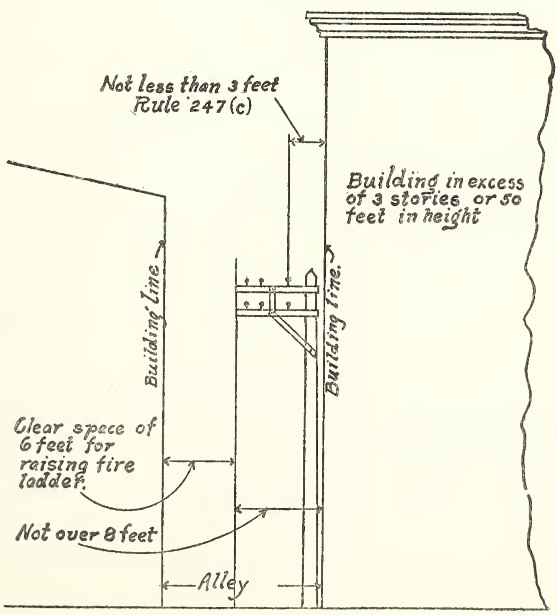

FIG. 9.

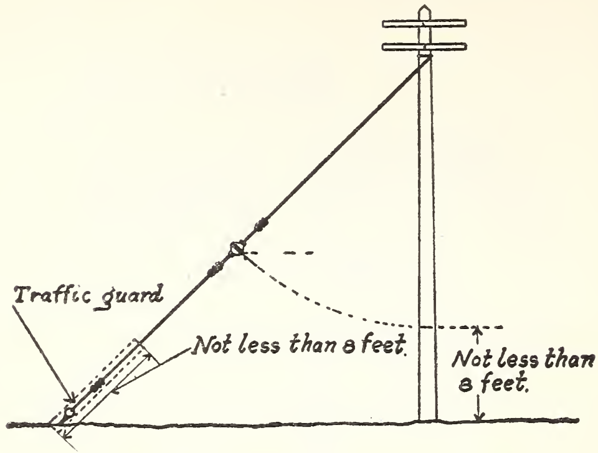

Fig. 10.—(*Rule 252*) *Strain insulator in guy wire*

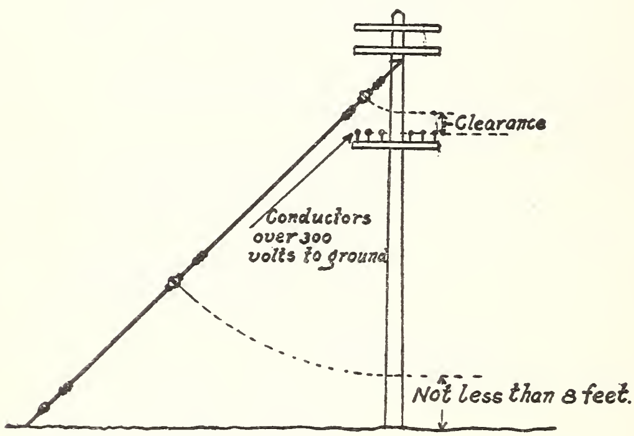

Fig. 11.—(*Rule 252*) *Strain insulators in exposed guy wires*

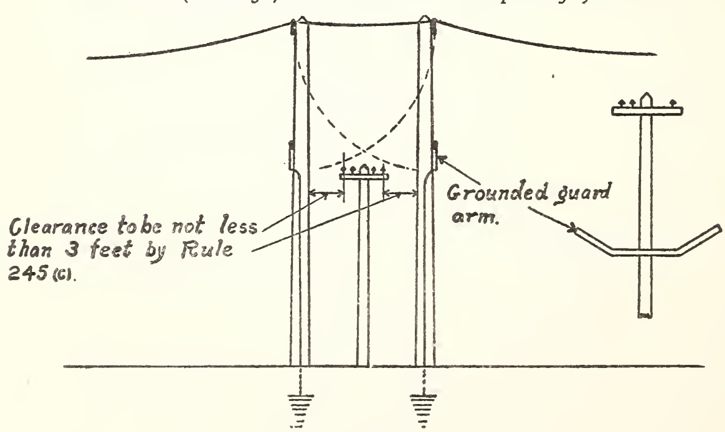

Fig. 12.—(*Rule 269*) *Short span crossing*

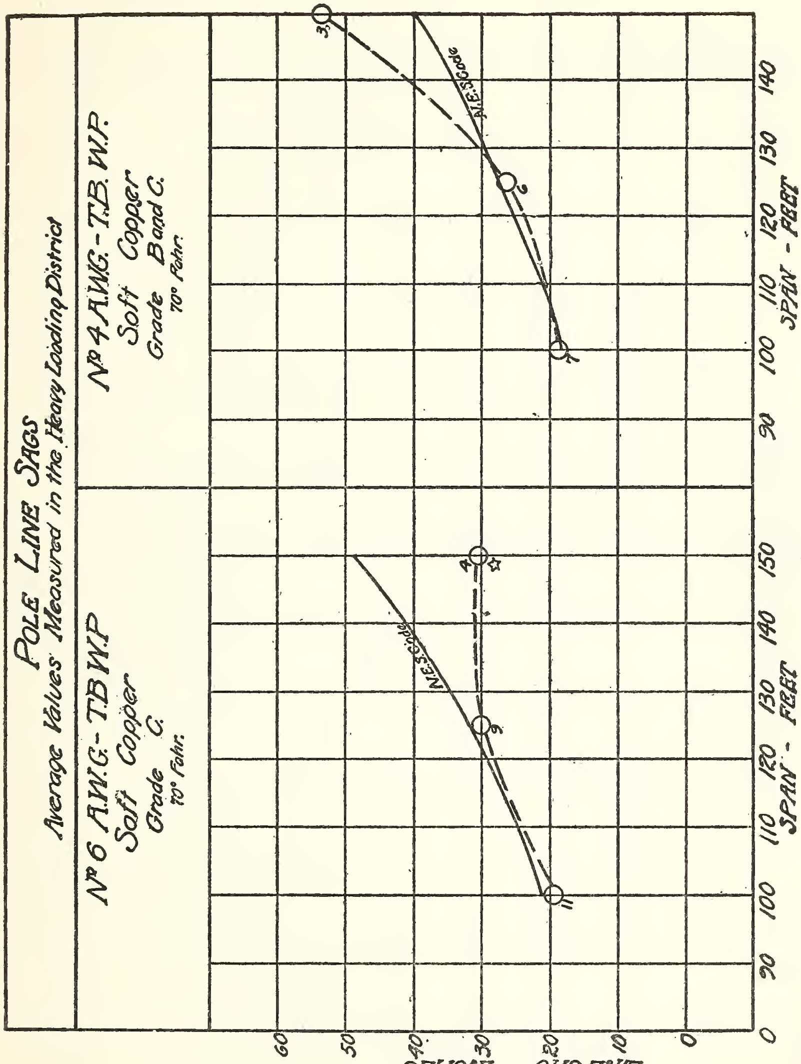

Fig. 13

Note.—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.

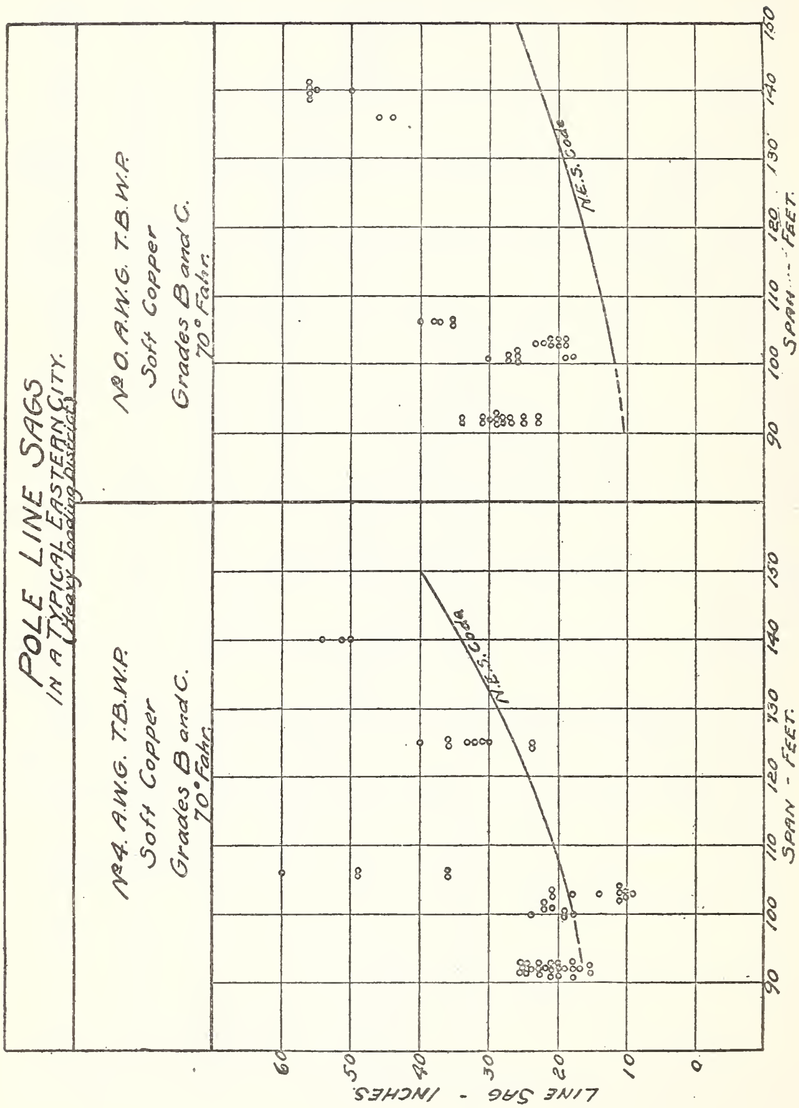
POLE LINE SAGS
IN A TYPICAL EASTERN CITY.
(Heavy loading District)
No. 4. A.W.G. T.B.W.P.
Soft Copper
Grades B and C.
70° Fahr.
No. 0. A.W.G. T.B.W.P.
Soft Copper
Grades B and C.
70° Fahr.
N.E.S. Code
N.E.S. Code
SPAN - FEET.
SPAN - FEET.
LINE SAG - INCHES.
90
100
110
120
130
140
150
60
50
40
30
20
10
0

FIG. 14

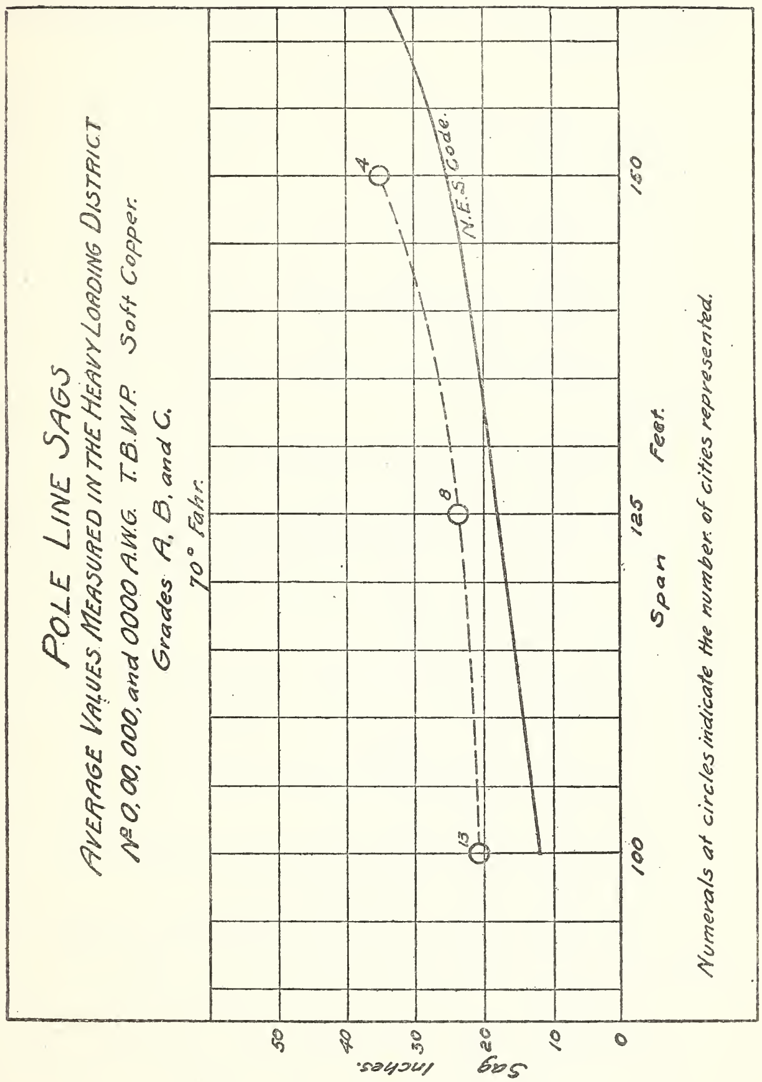
POLE LINE SAGS
AVERAGE VALUES MEASURED IN THE HEAVY LOADING DISTRICT
No 0, 00, 000, and 0000 A.W.G. T.B.W.P. Soft Copper.
Grades A, B, and C.
70° Fahr.
N.E.S. Code.
4
8
13
100
125
150
Span Feet.
0
10
20
30
40
50
Sag Inches.
Numerals at circles indicate the number of cities represented.

Fig. 15

Part 3.—RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRICAL UTILIZATION EQUIPMENT

CONTENTS

Sec. 30. PROTECTIVE ARRANGEMENTS

300. Scope of the Rules

(*a*) The following rules apply to electrical utilization equipment between 25 volts and 750 volts, where accessible to other than qualified electrical operators, as in mills, factories, mercantile establishments, hotels, theaters, and other public buildings, cars and other vehicles, dwellings, and similar places. Signal equipment connected to signal lines (see definition 4) is exempted, except from rules under section 39.

(*b*) Equipment and conductors exceeding 750 volts, in addition to complying with the rules for stations and such of the following rules as apply, shall, where accessible to other than qualified electrical operators, have all ungrounded current-carrying parts either incased in permanently grounded metal cases or conduits, or otherwise suitably guarded to prevent access or too close approach to such current-carrying parts by any but specially authorized persons.

(*c*) Electrical utilization equipment, however, as well as generating equipment, if inclosed in a separate room which is inaccessible to unauthorized persons, and when in service is under the control of a qualified electrical operator whose attention is not distracted by other processes, shall be installed in conformity with the rules applying to Electric Supply Stations (Part I) and does not come under these rules.

301. Application of the Rules

(*a*) The rules are intended to apply to all such installations except as modified or waived by the proper administrative authority or its authorized agents. They are intended to be so modified or waived in particular cases wherever any rules are shown to involve expense not justified by the protection secured or for any other reason to be impracticable; or wherever it is shown that equivalent or safer construction can be more readily provided in other ways.

Other methods of construction and installation than those specified in the rules may be made as experiments to obtain information if done where supervision can be given by the proper administrative authority.

(*b*) The intent of the rules will be realized (1) by applying the rules in full to all new installations, reconstructions, and extensions, except where any rule is shown to be impracticable for special reasons, or where the advantage of uniformity with existing construction is greater than the advantage of construction in compliance with the rules; (2) by placing guards on existing installations or otherwise bringing them into compliance with the rules, except where the expense involved is not justifiable.

The time allowed for bringing existing installations into compliance with the rules will be determined by the proper administrative authority.

(*c*) It will sometimes be necessary to modify or waive certain of the rules in cases of temporary installations or installations which are shortly to be discarded or reconstructed.

(*d*) In cases of emergency, or pending decision of the administrator, the person responsible for the installation may decide as to modifications or waiver of any rule, subject to review by proper authority.

302. General Requirements

(*a*) All electrical utilization equipment shall be of such construction and so installed and maintained as to reduce the life hazard as far as practicable.

(*b*) Compliance with the requirements of the National Electrical (Fire) Code for the installation of wiring and fittings is recommended.

(*c*) Where materials or devices are available which have been subjected to examination by some properly qualified body and found to comply with the general requirements of the National Electrical Safety Code, the National Electrical Code, and other nonconflicting accepted standards which apply for any given purpose, such materials or devices should be used in preference to others which have not been so examined regarding their suitability for the given purpose.

In order to avoid the necessity for repetition of such examinations by different examiners, frequently with inadequate facilities for such work, and to avoid the confusion which would result from conflicting reports as to the suitability of devices examined for a given purpose, it is necessary that such examinations should be made under standard conditions, and the record made generally available through promulgation by organizations properly equipped and qualified for experimental testing, inspections of the run of goods at factories and service value determinations through field inspections, and whose findings are subject to appeal to the Bureau of Standards.

303. Inspections and Repairs

(*a*) Electrical utilization equipment shall comply with these safety rules when placed in service, and shall thereafter be periodically inspected, and when necessary, cleaned. Defective equipment shall be put in good order or permanently disconnected. Defective wiring, where hazardous, shall be repaired or removed.

(*b*) Repairs, extensions, and changes should be made to existing utilization equipment and conductors only by properly qualified persons.

304. Grounding

(*a*) Grounding Method.—All lightning-arrester grounding and all grounding of circuits, equipment, or wire runways, which is intended to be a permanent and effective protective measure shall be made in accordance with the methods specified in section 9.

(*b*) Circuits Required to be Grounded.—All circuits installed in rooms to which other than properly qualified electrical workmen have access, or in rooms where nonelectrical processes are liable to distract the attention of the electrical operator from the purely electrical operations, shall be permanently grounded in accordance with the rules of section 9, Method for Protective Grounding, except that the following circuits are not required to be grounded:

(1) Circuits on 2-wire direct-current systems.

(2) Circuits entirely unexposed to leakage or induction from higher voltage circuits, either through overhead construction or through transformers or other devices.

It is recommended, however, that all 3-wire (not delta 3-phase) circuits, even if unexposed, have their neutrals grounded; and that multiphase circuits, even if unexposed, where partly used for lighting, be so arranged and grounded that the lighting circuits have the lowest practicable votage ground.

(3) Circuits over 150 volts to ground. (See rule 306.)

(4) Electric furnace and welding circuits. (See rule 352.)

(*c*) Grounding Noncurrent-Carrying Metal Parts.—Under the hazardous conditions named below fixed electrical utilization equipment shall, when practicable, have the exposed noncurrent-carrying metal parts, such as frames of motors, cranes, cars, and switchboards, cases of transformers and oil switches, and casings of wiring and conductors permanently grounded. (See sec. 9, and for grounding of portable devices see sec. 37.)

The following conditions shall be considered hazardous:

(1) All operation at voltages over 150 to ground, wherever equipment is located.

(2) All locations where explosives, inflammable gas, or inflammable flyings normally exist in dangerous quantities.

(3) All cases where exposed grounded surfaces, such as metal frames of other machines, plumbing fixtures, conducting floors or walls, exist within the reach of persons when touching the metal parts under consideration. Usually grounded surfaces within 5 feet horizontally of the parts considered and within 8 feet vertically of the floor are considered "within reach."

(*d*) Exceptions.—Except in cases (2) and (3) under the preceding paragraph, no ground connection need be made to exposed metal frames of switchboards, motors, or lighting fixtures connected to direct-current trolley or third-rail circuits, provided that such frames are effectively insulated from ground, and provided that the metal frames in question are so located with reference to insulating floors or platforms that persons can not readily touch the metal frames in question without standing on such floors or platforms.

(*e*) Parts of machines, such as name plates, screws in wood, and similar small parts which are not liable to become alive, except under very unusual circumstances, are not considered as coming under the rule and may be left ungrounded.

305. Working Space About Electrical Equipment

(*a*) Suitable working space should be provided and maintained about all electrical utilization equipment.

(*b*) The working spaces should, where practicable, have minimum horizontal dimensions, where adjacent to exposed live parts within 8 feet of floor, as follows:

(1) Parts above 150 volts to ground, if on one side, 2.5 feet; if on two sides, 4 feet.

(2) Parts below 150 volts to ground, if on one side, 1.5 feet; if on two sides, 2.5 feet.

(*c*) Where adjacent to such exposed live parts, working spaces should be so arranged that they will not be used as passageways.

(*d*) The elevation of the equipment at least 8 feet above ordinarily accessible working platforms affords protection at least equivalent to that provided by the horizontal clearances of (*b*), and may be used in lieu thereof, if desired.

306. Guarding or Isolating Live Parts

(*a*) All ungrounded current-carrying parts of electrical utilization equipment, such as bus bars, conductors, and terminals, operating at over 150 volts to ground and not isolated by elevation at least 8 feet above floor line should, where practicable (for exception see paragraph *b*), be provided with suitable permanent inclosures or other guards arranged so as to prevent persons or conducting objects from inadvertently coming (or being brought) in contact with the parts in question, and at the same time so as to permit ready access to authorized persons for making adjustments or repairs.

Inclosures may consist of suitable casings or suitable insulating coverings. The continuous insulating covering of conductors should be depended upon only when the circuit is grounded or entirely unexposed to leakage or induction from higher voltage circuits, and where it is impracticable to install more suitable guards. It should be depended upon then only when the covering is not exposed to liability of mechanical injury (see rule 313 *b*), and is very substantial, thoroughly dry, and contains no noninsulating flame-proofing compound or oil-soaked rubber. It is recommended that in addition to the protection afforded by such coverings the insulating mats or platforms called for in paragraph (*b*) be used.

Where covers, casings, or barriers must at any time be removed from the otherwise exposed current-carrying parts which they guard, while these parts are alive, the covers, casings, or barriers should be of insulating material, or so arranged that they can not readily be brought in contact with the live parts.

Mats may be of wood, held together by wood pins, or of cork matting, linoleum, or rubber. The material and construction should be suitable for the voltage concerned and for the prevailing conditions. If subject to moisture or to accumulations of conducting dust, flyings, or chips, mats should present surfaces minimizing the hazards from these sources.

(*b*) Where current-carrying parts at over 150 volts to ground must necessarily be exposed (unguarded) within 8 feet from the floor line, all surrounding conducting floors and other noncurrent-carrying surfaces within reach shall be covered with suitable insulating platforms, mats, or other insulating devices. (See rule 305 for working space.)

The guarding of current-carrying parts will obviate the necessity for such insulating devices, and where the use of the latter is impracticable, from the nature of the location or processes carried on, guards should always be used.

(*c*) Except on fenced rights-of-way or other locations to which only qualified persons are admitted, trolley or crane collector wires and third rails, whether indoors or out, shall be so isolated by elevation (see rule 116 and section 24) or be provided with suitable guards so arranged that persons can not inadvertently touch the current-carrying parts while in contact with the ground or with conducting material connected to the ground, and shall be provided with warning signs effective whenever the conductors are alive.

Damp wood, concrete floors, and metal parts of crane cabs are considered as grounded.

Trolley-contact conductors indoors shall be so supported that in case of a single break contact with the floor can not be made.

(*d*) Bare parts at different potentials shall be effectively separated. Such parts in circuits of large capacity or operating at over 300 volts shall, where practicable, unless provided with the inclosure or other guard specified in (*a*) above, be provided with suitable barriers, if otherwise they would be liable to be short-circuited by tools or other conducting objects.

307. Hazardous Locations

(*a*) In locations where explosives, inflammable gas, or inflammable flyings normally exist in dangerous quantities all parts at which sparking or arcing is liable to occur shall be so inclosed as to reduce the hazard as far as practicable.

(*b*) This protection should be obtained by one of the following methods:

(1) By placing in separate compartments or rooms, free from explosives, inflammable gas and inflammable vapors.

(2) By using casings of the inclosed type (ventilated, if necessary) when dust or flyings are present.

(3) By using explosion-proof casings when inflammable gases exist in dangerous quantities.

(*c*) All casings shall be nonabsorptive and noncombustible, and when of metal shall be permanently grounded, if within reach of grounded surfaces, or if inflammable gas is present.

308. Storage Batteries, Transformers, and Lightning Arresters

(*a*) The installation of nonportable storage batteries above 50 kilowatt-hour capacity, at the 8-hour rate of discharge, shall be in accordance with the requirements given in section 13 of the rules for stations. Where small storage batteries (not included under section 13) are placed in rooms used also for other purposes, adequate guards or inclosures shall be provided, when necessary, to prevent the approach of unauthorized persons, and special means of ventilation when necessary to prevent the accumulation of inflammable gas. For all batteries whose operating voltage exceeds 150, construction shall comply with rules 133 and 306 *b*.

(*b*) The installation of transformers having either winding over 300 volts to ground shall comply with the rules of section 14 of the rules for stations, and if the operating voltage of any winding exceeds 750, the transformers shall be made inaccessible to unauthorized persons. (See also rule 304 *c* and discussion on section 14.)

(*c*) The installation of lightning arresters shall comply with the rules of section 18 of the rules for stations and, if the operating voltage of the circuit exceeds 750 volts, the arresters shall be made inaccessible to unauthorized persons.

309. Identification

(*a*) All electrical utilization equipment shall be suitably identified, when necessary for safety.

(*b*) The identification may be by position, color, number, name plate, label, design, or other means.

(*c*) The voltage and intended use shall be shown where important.

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Sec. 31. CONDUCTORS

310. Electrical Protection

(*a*) Conductors shall be suitable for the location, use, and voltage, and each conductor (except neutral conductors, ground wires, and conductors of circuits the opening of which may cause special hazard by the interruption of service or removal of protection) shall be protected against excessive current by a suitable automatic cut-out or by the design of the system.

(*b*) Neutral conductors in 3-wire systems shall be arranged without automatic cut-outs interrupting their continuity, unless the cut-out opens all conductors of the circuit with one operation. Switches in 3-wire circuits shall open all conductors of the circuit with one operation, except that the switch may be omitted from the neutral. The neutrals shall everywhere be of sufficient size to safely carry the maximum current in either outer conductor at that point.

In 2-wire branches from 3-wire circuits the conductor connected to the neutral is not for the purpose of this rule considered a neutral conductor.

(*c*) All conductors normally grounded for the protection of persons shall be arranged without automatic cut-outs interrupting their continuity between the source of electrical supply and the point at which the ground wire is attached, unless the cut-out opens all conductors of the circuit with one operation. Switches shall open all conductors of the circuit with one operation, except that the switch need not be placed on a grounded conductor of the circuit and except that this does not necessarily apply to single-pole key sockets which may be used and in which the switch may be placed on the grounded side.

Where the utilization equipment is connected to electrical supply lines, the point of connection to the service leads is considered as the source of electrical supply.

The identification of neutral and grounded conductors by some suitable marking will facilitate compliance with the rule.

311. Mechanical and Thermal Protection

(*a*) Where exposed to mechanical injury, suitable casing, armor, or other means shall be employed to prevent injury or disturbance to conductors, their insulation, or supports. Conductors used as meter loops shall be substantially supported clear of objects other than their insulating supports, and separated from each other, or shall be in approved conduit or substantial noncombustible, nonabsorptive casings.

(*b*) Where conductors with combustible insulating coverings are closely grouped (as sometimes on the rear of switchboards or in cable ways) they shall have a substantial noncombustible outer covering. Conductors in very hot locations shall have a noncombustible insulating covering.

(*c*) Bare conductors shall be used only for switchboard, panel board, or storage-battery connections; or for electrolytic, low voltage furnace, or low voltage welding circuit, and similar connections; or for trolley wires, third rails, and other contact conductors and parts at different potentials. Such bare conductors shall be fixed at adequate separations by the use of suitable supports. Except at the point where a permanent ground connection is made such conductors within buildings shall be kept insulated from the ground. Bare conductors shall not be used where inflammable gases or explosives are liable to exist in large quantities. (See rules 306 and 312 for guarding requirements; also see rule 91 *c*.)

312. Isolating or Guarding

All fixed conductors having insulating coverings and operating at over 300 volts to ground, and bare conductors at all voltages shall (unless guarded as required in rule 313) be so isolated by elevation (as required by rule 306 *a*) that no person can inadvertently come or bring conducting objects in contact with them.

313. Guarding Conductors

(*a*) Use of Inclosing Casings.—For inclosing insulated conductors, approved permanently grounded metal conduit, waterproof insulating conduit, or grounded metal sheathing shall be used, except that in dry places, ducts, runways, or compartments of suitable fire-resistive material, may be used for conductors below 750 volts, if containing no exposed combustible material. (See rule 318 for further exception.) In damp places conduit shall be made waterproof and provided with suitable means for draining off condensation, unless the conductors contained are lead-sheathed cable.

(*b*) Open Conductors Below 750 Volts.—Where open insulated conductors between 300 volts to ground and 750 volts, or open bare ungrounded conductors at any voltage below 750 volts (except bare wires used at high temperatures in heating devices, at voltages not exceeding 300 volts to ground) are necessarily brought closer to the floor line than 8 feet, they shall be guarded by permanent screens or inclosures.

(*c*) Where persons at any time remove or pass by screens or other guards for bare conductors while such conductors are alive, such screens or guards shall be of insulating material, and all conducting floors, walls, machine frames, and similar surfaces within 8 feet below the conductors or 3 feet horizontally from them, shall be covered with suitable insulating platforms, mats, or covers. (See rule 306 *b*.)

Dependence should not be placed on the unprotected insulating covering as a suitable guard or inclosure for such conductors near the floor line, nor in certain other cases (see rule 306 *a*). Other guards should be provided to protect the insulation against mechanical injury and to secure the safety of persons who must come near the conductors.

314. Guarding in Damp or Hazardous Locations

(*a*) Conductors in damp locations or where exposed to corrosion, if not in waterproofed conduit, or in waterproof metal sheaths in other suitable ducts, shall be effectively isolated and supported on insulators of a suitable type.

(*b*) Conductors in locations where inflammable gas or flyings normally exist shall be in grounded metal conduit or metal-sheathed cable. All fittings and outlets of such conduit and cable shall be electrically and mechanically continuous with the conduit or metal sheath, and the conduit shall be sealed by the use of suitable potheads or equivalent devices to prevent entrance of gases.

315. Precautions to Avoid Excessive Inductance and Eddy Currents

Supply conductors of alternating-current or direct-current circuits should not be run in separate iron conduits or on opposite sides of I beams or other iron structures or be otherwise run so as to increase abnormally the self-inductance of the circuit.

Such construction, by introducing large self-inductance in direct-current circuits, causes fuses to blow explosively; in alternating-current circuits it causes heating due to eddy currents in the metal.

316. Pendants and Portables

Pendants or portable conductors shall not be installed or used on circuits operating at over 300 volts to ground, unless they are accessible only to persons authorized to approach them. In such cases they shall be of a type suitable for the voltage and conditions, and conform to the rules of section 37.

317. Taping Ends and Joints

Ends and joints of insulated conductors, unless otherwise adequately guarded, shall have equal insulating covering with other portions of the conductor, and this covering shall be securely held in place.

318. Grounding or Isolating Service Conduits

(*a*) Metal conduit or sheathing encasing service conductors from either overhead or underground lines shall either be (1) permanently grounded as required by rule 304, or (2) effectively isolated by elevation. (See rules 304 and 306.)

(*b*) If not grounded, the service conduit or sheathing shall be effectively insulated from metal work of the building, and from its piping. Where service conduit or sheathing is electrically continuous with interior conduit or sheathing, the grounding required for conduit (by rule 304 *c*) shall be made direct to the service conduit or sheathing and shall have conductance not less than that of No. 6 copper wire.

(*c*) Where grounded service conduit or sheathing is insulated from interior conduit or sheathing, its ground wire conductance need not exceed that required under section 9, for equipment ground wires.

It is frequently advisable to insulate interior conduit or sheathing from underground service conduit or sheathing, to prevent burnouts of small interior conduit, armored cable sheaths or metal molding, by large currents which might flow from grounded circuits through the interior metal to water pipes or other good ground connections within the building.

319. Temporary Wiring

Temporary wiring and equipment, which is not in compliance with these rules, may be used, but only when under competent supervision, or protected by suitable barriers or warning signs while it or neighboring wiring is alive and accessible to any person.

Sec. 32. FUSES AND OTHER CUT-OUTS, SWITCHES AND CONTROLLERS

320. Accessible and Indicating

All switches, automatic cut-outs, controllers, starting rheostats, auto-starters, and other control devices shall be readily and safely accessible to authorized persons; they shall be so located or marked when controlling circuits of over 1320 watts, as sufficiently to indicate their function and the location and character of the equipment controlled by them and whether they are open or closed. They shall be so installed as to minimize the danger of accidental operation. Where practicable, they shall be so installed that gravity can not close them; and such switches as close by gravity shall be provided with a proper stop block or latch to prevent accidental closing.

Switches controlling emergency lighting circuits, elevator circuits, circuits in theaters, hospital operating rooms, and other circuits, the interruption of which might cause special hazard, shall be arranged so as to be accessible only to authorized persons.

321. Hazardous Locations

When necessary to install fuses or other automatic cutouts, or switches or other control devices in locations where explosives, inflammable gas or inflammable flyings exist, they shall be suitably protected. (See rule 307.)

322. Where Switches are Required

(*a*) Suitable switches shall be inserted in all feeder conductors connecting utilization installations to service connections from either overhead or underground lines. These switches shall be readily accessible, and as close as practicable to the point of connection with overhead or underground lines.

(*b*) Suitable switches shall be inserted in all circuit leads (except a grounded conductor, see rule 310) to motors, transformers, storage batteries, electric furnaces, and similar utilization equipment, except between parts or pieces of apparatus intended to operate as a unit

Switches installed for use on lighting and similar circuits under 1320 watts are not required to interrupt all conductors of the circuit.

(*c*) Switches or plug connectors shall be placed in all circuit leads at the point where temporary wiring or portable conductors are connected to the permanent wiring.

323. Character of Switches and Disconnectors

(*a*) Capacity.—Switches used otherwise than as disconnectors shall have a rated capacity such as to insure safe interruption, at the working voltage, of the greatest current which they will be required to carry continuously, and shall be marked with the current which they can safely interrupt.

Rating means that they should operate successfully at 50 per cent overload in amperes and at the working voltage under the most severe conditions which they are liable to meet in practice.

(*b*) Disconnectors shall be of suitable voltage and ampere rating for the circuit in which they are installed and shall be accessible only to properly qualified persons. They shall also be protected by signs warning against opening the switches while carrying current in excess of the safe opening limit.

Interlocking arrangements are desirable to prevent opening of such disconnectors under loads beyond their safe opening capacity.

(*c*) Locking or Blocking.—Means shall be provided so that switches controlling motors, storage batteries, transformers, electric furnaces, and similar utilization equipment can be locked or blocked in the open position and plainly tagged to prevent careless closing while work is being done on the equipment controlled by them, unless all live and moving parts of controlled equipment which would cause a hazard are so guarded as to render locking or blocking unnecessary.

Small capacity snap switches, if near machines and in plain sight from all parts of the machines controlled, are exempted. Switches of any size are exempted if the installation comprises only one motor, and the switch is in plain sight from all parts of the machines operated by the motor.

Locking is recommended rather than blocking, wherever parts of the machinery driven are remote from the point of control.

(*d*) Good Contact.—Switches, controllers, and rheostats shall be so constructed as to make and maintain good contact. Knife switches shall maintain such alignment under service conditions that they may be closed with a single unhesitating motion.

324. Disconnection of Fusible Cut-outs Before Handling

(*a*) Fusible cut-outs in circuits operating at over 150 volts to ground, shall, if practicable, where accessible to others than qualified electrical attendants, be so arranged that the ungrounded current-carrying parts can not be touched by persons re-fusing the cutout until the fuses have been disconnected from all sources of electrical energy. Where the circuit voltage exceeds 300 to ground, this arrangement shall always be made. It is recommended that where practicable this protection also be provided for fusible cut-outs in circuits operating below 150 volts to ground.

This may be accomplished by a construction in which the fuse and its exposed current-carrying connections are accessible only after they have been disconnected from the circuit, either by opening the fuse inclosure or by other means.

(*b*) On circuits not exceeding 150 volts to ground, where the fusible cut-outs are not arranged so that they are necessarily disconnected from all sources of electrical energy before the ungrounded current-carrying parts can be touched, it is recommended that switches be so placed or arranged that opening them will disconnect the fuses from all sources of electrical energy.

On circuits between 150 and 300 volts to ground, where fusible cut-outs are not arranged so that they are necessarily disconnected from all sources of electrical energy before the ungrounded current-carrying parts can be touched, switches shall always be so placed or arranged that opening them will disconnect the fuses from all sources of electrical energy unless portable insulating appliances are provided for handling the cut-outs.

(*c*) Where fusible cut-outs are in locked cabinets or otherwise made inaccessible to all but qualified persons, sufficient protection is usually secured, even for voltages above 300, by the use of switches accessible only to such persons, these switches to be placed or arranged so that their operation will disconnect the fuses from all sources of electrical energy.

325. Arcing or Suddenly Moving Parts

(*a*) Fuses and circuit breakers shall, as far as possible, be so located and shielded that persons will not be burned by their operation.

(*b*) Handles or levers of circuit breakers and similar parts which may move suddenly in such a way that persons in the vicinity are liable to be injured by being struck by them shall be guarded or isolated, where practicable.

326. Grounding Noncurrent-Carrying Metal Parts

Exposed noncurrent-carrying metal parts of switch and fuse cases, levers, and other similar parts to which leakage may occur from live parts shall be permanently grounded according to the provisions of rule 304.

Parts of machines, such as name plates, screws in wood, and similar small parts which are not liable to become alive except under very unusual circumstances are not considered as coming under the rule and may be left ungrounded.

327. Guarding Live Parts of Switches and Automatic Cut-outs

(*a*) All manual switches (with the exception stated below) shall have suitable casings or guards protecting the operator from danger of contact with current-carrying parts, or shall be provided with insulating handles and suitable insulating guard disks or shields so arranged between the handles and the live parts as to prevent the hand from slipping into contact with live parts or being burned by arcing at the switches.

Switches under 150 volts to ground and limited to 60 amperes by cut-outs in series are not required to conform with the above paragraph.

(*b*) Current-carrying parts of switches or automatic cut-outs operating at over 150 volts to ground shall be provided with inclosing guards, effective during ordinary operation, if accessible to other than properly qualified persons.

Switches or automatic cut-outs operating at over 150 volts to ground and having current-carrying parts exposed may be made inaccessible to other than properly qualified persons by inclosure in locked cabinets or rooms.

(*c*) Where switches or cut-outs above 150 volts to ground are not guarded during operation suitable insulating floors, mats, or platforms shall be provided on which the operator must stand while operating the switches or adjusting automatic cut-outs, and (unless operators invariably wear suitable insulating gloves while handling the switches) any conducting walls or machine frames within 3 feet shall be provided with suitable insulating guards.

The suitable guarding of live parts will obviate the necessity for such insulating floors and other devices, and where use of such devices is impracticable from the nature of the location or mechanical process carried on, guards should always be used.

(*d*) Switches shall, if practicable, be so connected as to have no live blades exposed to contact when a switch is open.

Sec. 33. SWITCHBOARDS AND PANEL BOARDS

330. Accessibility and Convenient Attendance

(*a*) Switchboards and panel boards shall have all switches so arranged that the means of control are readily accessible to the operator.

(*b*) Instruments, relays, or other devices requiring reading or adjustment shall be so placed that work can be readily performed from the working space provided. (See rule 335.)

331. Location.

Switchboards shall, where practicable, be so placed that the persons necessarily near the board will not be endangered by machinery or equipment located near the board. Means for adequate illumination shall be provided.

332. Arrangement and Identification

(*a*) Connections, wiring, and equipment of switchboards and panel boards shall be arranged in an orderly manner and all switches and cut-outs shall be plainly marked, labeled or arranged so as to afford ready means for identifying circuits or equipment supplied through them.

It is recommended that a diagram of switchboard or panel board connections and devices be kept posted in some convenient place near such equipment.

(*b*) Switchboards shall have current-carrying parts which are ordinarily isolated or guarded, but which may occasionally require adjustment or repair while alive, so arranged that suitable portable covers or shields can be effectively placed to protect workmen from contact with any neighboring live parts.

333. Spacings and Barriers Against Short Circuit

(*a*) Exposed bare parts of different potential on any switchboard or panel shall be as few as practicable and these parts shall be effectively separated.

(*b*) Such parts, including bus bars, should, when practicable, be so located or provided with such barriers or substantial insulating coverings that parts of different potential will not be accidentally short-circuited by tools or other conducting objects.

334. Grounding Frames

Switchboard frames and metal cabinets should be permanently grounded, under the conditions and with the exceptions noted in rule 304.

335. Guarding Current-Carrying Parts

(*a*) All switchboards and panel boards having exposed current-carrying parts operating at over 150 volts to ground and not isolated by elevation at least 8 feet above the floor shall when practicable be suitably inclosed in locked cabinets, screens, or rooms, or other inclosures to make them inaccessible to others than the authorized operator. Conducting floors about such boards shall be provided with a suitable insulating platform or mat so placed that no person can inadvertently touch live parts unless standing on the insulating platform or mat. (See rules 306 and 327 *a*.) Where the circuit voltage exceeds 300 to ground this arrangement shall always be made.

(*b*) Where switchboards or panel boards at voltages below 150 to ground are accessible to other than properly qualified operators, they should, where practicable, be inclosed in cabinets or screens as an effective precaution against accidental short circuits (see rule 333) at times when no operation of the board necessitates the opening of the cabinet or screen.

(*c*) Plug type switchboards on constant-current systems, or if above 150 volts to ground, shall have no current-carrying parts exposed on face of boards, and plug connectors shall have all current-carrying parts guarded as long as they are alive.

(*d*) Switchboards having no current-carrying parts exposed at the face (working space) are recommended for use in theaters and similar places where rapid handling is necessary, and the attention must be given to signals or to other processes.

(*e*) Theater switchboards at any voltage, if having current-carrying parts exposed at the face, should, where practicable, be elevated, or guarded by suitable railings, to prevent contact with live parts by passers-by.

Sec. 34. MOTORS AND MOTOR-DRIVEN MACHINERY

340. Control Devices

(*a*) Separately excited direct-current motors, also series motors, and motor generators and converters larger than 10 kilowatts where it is possible for them to be driven at excessive speed from the direct-current end, as by a reversal of current or decrease in load, shall be provided with speed-limiting devices, unless the load and the mechanical connection thereto are of such a character as to safely limit the speed.

(*b*) Where the speed control of direct-current motors is accomplished by varying the field resistance, and the nature of the load and the range of the field rheostat are such as to make a dangerous speed attainable, and no speed limit devices are used, the field rheostats shall be arranged with no-voltage releases or other devices so that the motor can not be started or continued in operation under dangerously weakened field, except where the operation of such a no-voltage release might result in serious injury to service or apparatus.

Motors which are designed to permit starting safely under weakened field are not included in the above.

(*c*) Manually controlled starters for motors shall be so designed and circuits so arranged that they return automatically to the "off" or starting position upon failure of the energy supply, except where the motors and their starting devices are, during operation, under supervision of qualified persons and equivalent protection is otherwise provided.

(*d*) Where speed-limiting devices or remote-control switches are electrically operated, the control circuits by which such devices are actuated shall be adequately guarded, by conduit or otherwise, against mechanical injury.

341. Hazardous Locations

Motors in which sparking or arcing can occur during operation, shall where practicable be kept out of locations where explosives or inflammable gas or inflammable flyings exist. Where necessarily in such locations they shall be suitably protected. (See rule 307.)

342. Deteriorating Agencies

(*a*) Suitable guards or inclosures shall be provided to protect exposed current-carrying parts of motors and the insulation of motor leads where installed directly under equipment or in other locations where dripping oil, excessive moisture, steam, vapors, chemicals, or similar injurious agents exist.

(*b*) The metal frames and other exposed noncurrent-carrying metal parts of equipment in these locations shall be permanently grounded. (See rule 304 *c*.)

343. Guards for Live Parts

(*a*) Motors operating at over 150 volts to ground, unless isolated by elevation at least 8 feet above the floor line, should, if practicable, be provided with permanent inclosures or other suitable guards so arranged as to prevent persons or conducting objects from inadvertently coming or being brought into contact with live parts or interfering with the operation of the motors.

(*b*) Suitable insulating mats or platforms of substantial construction and providing good footing shall be so placed on floors and, if necessary, on frames of machines having exposed live parts above 150 volts to ground that the operators or other persons in the vicinity can not readily touch such parts unless standing on the mats, platforms, or insulating floors.

The suitable guarding of live parts by inclosures or barriers effective during attendance or necessary adjustments of live parts will obviate the necessity for insulating mats, and, where such mats are impracticable from the nature of the location or processes carried on, guards shall always be used.

Where connectors are used in motor leads, these should be provided with insulating covering equal to that on the conductors.

(*c*) Where necessary, steps and handrails should be installed on or about large machines to afford safe access to live parts which must be examined or adjusted during operation.

(*d*) Where two or more machines, either of which operates at over 150 volts to ground, are mechanically coupled together, and the operator can touch the frames of more than one at a time, the frames of all such machines shall be permanently grounded, unless they are bonded together electrically and surrounded by insulating mats or platforms on which persons must stand in order to touch the machine frames. If operating at above 300 volts to ground, their frames shall always be grounded, and frames shall also be grounded wherever, from the nature of the location or of processes carried on, the use or maintenance of insulating mats or platforms is impracticable. (See rule 304 *c*.)

344. Protecting Moving Parts

Suitable guards or inclosures shall be arranged at each motor or motor-driven machine when necessary to prevent persons or objects from inadvertently coming in harmful contact with moving parts, including chains, belts, gears, and pulleys.

Sec. 35. ELECTRIC FURNACES AND WELDERS

350. Protection from Burns

(*a*) Electric furnaces and apparatus used for arc welding, where intensely glowing, incandescent, or arcing parts are exposed, shall be inclosed, so that those parts will not be accessible or visible to unauthorized persons.

(*b*) Suitable protecting screens, hoods, goggles, gloves, and other devices shall be provided for the authorized operators who must work or come near such exposed parts.

351. Grounding

The outside noncurrent-carrying metallic frames of furnaces shall be permanently grounded if they contain current-carrying parts connected to circuits above 150 volts to ground, or if the circuit within is not grounded and is exposed through transformer windings to a circuit over 150 volts to ground.

352. Guarding Live Parts

Except at points where necessarily left exposed (as at spot welder contacts), all current-carrying parts of furnaces, welders, and control equipment shall be suitably guarded with inclosures or barrier guards.

Sec. 36. LIGHTING FIXTURES AND SIGNS

360. Grounding

The exposed noncurrent-carrying metal parts of all lighting fixtures and other similar fixed electrical devices shall be permanently grounded when used under the following circumstances (for exception, see rule 304 *d*): (1) When in locations where explosives, inflammable gas, or inflammable flyings normally exist in dangerous quantities; (2) when within touching distance or about 8 feet from metal, concrete, or permanently damp floors or stairways, including fire escapes, galleries, or bridges, as in machine shops, stables, laundries, etc.; (3) when readily accessible from the ground or floor and also within 5 feet from conducting surfaces, such as metal piping, metal radiators, stoves, furnaces, plumbing fixtures, damp walls, or similar conducting surfaces, as in kitchens, machine shops, print shops, etc.

On grounded systems it is recommended that the center contacts of sockets and receptacles be connected to the ungrounded side of the system, and the inner screw shell of the devices to the grounded side or neutral, in order to reduce the liability of breakdown of the dielectric between the inner screw shell and the grounded outer brass shell, and also to reduce the liability of injury to persons in replacing lamps. This is especially important in wiring electric signs.

In lieu of grounding the external metal parts of lamp sockets, where suitable means for grounding are not readily available (as sometimes is the case with knob and tube wiring not near plumbing fixtures), sockets and lamp guards or similar devices of suitable insulating material may be used. It may be preferable, however, to place the socket itself out of reach and arrange for its operation by a chain pull having adequate insulation in the chain.

361. Insulation

Electric fixtures shall be provided with an adequate and mechanically protected dielectric (complying with the standardization rules of the A. I. E. E.) interposed between ungrounded current-carrying parts and those external surfaces which persons can touch.

Those current-carrying parts of grills, heaters, and other heating devices, which operate at high temperatures and are necessarily exposed, are exempted. (Compare rule 352.)

362. Exposed Live Parts

Electric fixtures, including lamp sockets and lamp bases, plugs, receptacles, etc., shall be so designed and installed that no current-carrying parts will normally be exposed externally. (For exception see rule 361.)

363. Accessibility and Guarding of Signs

(*a*) Electric signs at an elevation greater than 30 feet above roadways or footways, or at an elevation above a roof greater than the distance from the edge of the roof, shall, if they require attendance while in position, be provided with substantial, safely accessible runways, ladders, or platforms from which all replacements and other necessary adjustments can be made. Provision for supporting workmen by safety belts should be made in the construction and installation of signs so located.

(*b*) Electric signs outside buildings shall have no ungrounded current-carrying parts normally exposed to contact of workmen on or in the building. (Compare rule 313 *b*.)

(*c*) The exposed noncurrent-carrying metal parts of a sign should be grounded if within reach of any grounded surfaces, including metal work of the building structure.

364. Control of Outdoor Signs

Electric signs, located as noted in rule 363, shall be provided with switches arranged to entirely disconnect all feed wires of the sign, and either located within sight of the sign or arranged so that they can be locked in the open position.

365. Connectors for Signs

Electric signs shall be so arranged that changeable connections can be made manually only by approved connectors in which all poles of the circuit are simultaneously interrupted. All current-carrying parts of pin and socket connectors shall be provided with approved guards; so as not to be exposed to contact.

366. Isolating or Guarding Lamps in Series Circuits

(*a*) Arc and incandescent lamps and other devices in series circuits, except in grounded circuits of which no part exceeds 150 volts to ground, shall be effectively isolated or suitably guarded.

(*b*) All metal cable or chain supports for lamps shall be effectively insulated from the lamp or shall be permanently grounded.

Isolation will ordinarily be deemed sufficient when a vertical clearance of 8 feet is provided from floors or other ordinarily accessible places within buildings, of 10 feet from footways outside buildings, and of 15 feet from roadways. Horizontal clearance from windows, porches, and other spaces accessible to the general public should be not less than 3 feet.

(*c*) Lamps shall be secured from falling on persons or traffic passing below, and the hanger, rope, chain, or other means adopted for holding the lamps shall be regularly and systematically inspected. Metal chains or wire cables used for lowering lamps in series circuits shall be interrupted by a suitable strain insulator the minimum height of which from the floor or ground shall be 8 feet, whether the lamp is in position or lowered.

367. Safe Access to Arc Lamps

A suitable device shall be provided by which each arc lamp or other device on series circuits may be safely and entirely disconnected from the circuit before it is handled, unless the lamps are accessible only to properly qualified persons, worked on only from suitable insulating stools, platforms or tower wagons, and treated always as under the full voltage of the circuit concerned.

Sec. 37. PORTABLE DEVICES, CABLES, AND CONNECTORS

(Not Including those for Signal Systems)

370. Insulation

(*a*) Portable devices shall be provided with an adequate dielectric (complying with the standardization rules of the A. I. E. E.) interposed between ungrounded current-carrying parts and those external surfaces which persons can touch.

Toasters, grills, or other heating devices in which the current-carrying parts at high temperature are necessarily exposed, are exempted. (Compare rules 352 and 361.)

(*b*) In locations where the dielectric is exposed to mechanical injury it shall be suitably protected.

371. Grounding

(*a*) The permanent grounding of frames of portable devices (especially in connection with voltages above 150 to ground, and for any voltage when the devices are used within 8 feet of the floor in locations such as bathrooms, laundries, etc., where persons may easily touch grounded surfaces at the same time as the device) is recommended as a safety measure, where this is practicable and suitable means are available, but can not, of course, be reasonably required unless such means are available.

Such grounding may be obtained by the use of a 3-wire portable cord with the portable device, one wire being used for the ground conductor and the connectors being properly designed so that wrong connections can not be made by the user of the device.

(*b*) In lieu of grounding the external metal parts of portable lamp sockets where suitable means (as above indicated) are not readily available, sockets and lamp guards or similar devices of suitable insulating material may be used, and should be used in the hazardous locations listed previously.

372. Cable Connectors

(*a*) Where used with portable conductors it is recommended that connectors be used which necessarily disconnect both or all poles from the live source of energy where the circuit is opened.

(*b*) Connectors shall be so constructed (with guards when necessary) that the person using them can not inadvertently come in contact with live parts, or be burned by arcing when interrupting the largest current for which they are rated or marked.

(*c*) The end of a separable connector which is left alive, or the two ends of a separable connector where both are connected to live circuits (as in battery charging), shall have live parts suitably guarded.

(*d*) Where connectors are attached to portable cables, suitable means shall be provided for relieving the terminal connections of cable from strains.

(*e*) Separable connectors should, where practicable, be so designed that the plugs will not fit receptacles rated for larger currents than the plugs.

373. Identified Conductors, Cords, and Connectors

Where used with portable devices, the cases of which are designed to be grounded (see also rule 371), the portable cable and the separable connectors (both to the device and to the circuit) shall, where practicable, be provided with identified parts; so that the ground conductor wire in both the fixed wiring and portable cable will always be attached to the proper terminals of the connectors. It is desirable that the fixed wiring also have suitable marking to distinguish the ground conductor from circuit conductors.

Separable connectors shall be so constructed that wrong connection between the two parts is impossible.

374. Use of Portables and Pendants

(*a*) Portable and pendant conductors shall not be installed or used on circuits operating at over 300 volts to ground, unless they are accessible only to persons authorized to approach them. In such cases they shall be of a type suited to the voltage and conditions.

In car houses and similar locations where service at low voltage is not available and where necessary to use low-voltage pendant, or portable lamps or other devices in series with lamps on trolley circuits, the devices should be used only with great caution and be placed preferably on the grounded side of the circuit concerned.

(*b*) Where portable conductors are required, fixed sockets or connectors shall be provided at safely accessible points, attached, where practicable, to the grounded side of the circuit, and so located that liability of such conductors being brought into dangerous proximity with other live parts will be reduced as far as practicable.

(*c*) Where exposed to dampness or corrosive influences, portable conductors shall be of a type specially suited, and where exposed to inflammable gas or flyings they shall be so protected or isolated by elevation that they can not be readily damaged. In the latter case connectors shall be so arranged as not to be exposed to accidental opening by persons handling the portable conductors or devices. Portable lamps in locations where explosives or inflammable gases are normally present shall be incased in vaporproof globes with suitable mechanical guards.

(*d*) Portable and pendant conductors shall be so installed that no strain is placed on the terminal connections and shall have no joints except at suitable fittings.

(*e*) The use of worn or defective portable and pendant conductors should be avoided because of the danger to users by wire strands piercing the insulating covering, or becoming exposed through abrasion of the covering.

Sec. 38. ELECTRICALLY OPERATED CARS, CRANES, AND ELEVATORS

380. Guarding Live and Moving Parts

(*a*) All current-carrying parts connected to circuits above 150 volts to ground shall be so isolated or guarded that no person can inadvertently come in contact with them. (See rule 306 for trolley wires, etc.)

(*b*) Conductors.—All conductors over 150 volts to ground in locations accessible to the public shall be run in conduit, armored cable, or molding, the exposed metallic parts of which shall be permanently grounded.

(*c*) Equipment.—Guards for the current-carrying parts of unisolated electrical equipment, such as controllers, motors, transformers, automatic cut-outs, circuit breakers, switches, and other devices, shall consist of cabinets, casings, or shields of permanently grounded metal or of substantial insulating material.

(*d*) Arcing or Suddenly Moving Parts.—All such parts of electrical equipment, including fuses and the handles and arc chutes of circuit breakers, shall be so isolated or guarded that the liability of persons being struck or burned by sparking, flashing, or movement during operation is reduced as far as practicable.

381. Grounding Noncurrent-Carrying Parts

(*a*) All exposed noncurrent-carrying metal parts of electrical equipment at over 150 volts to ground shall be permanently grounded. In electric cars all steam or hot-water heating devices accessible to the public shall also be grounded.

The ground connection through well-bonded track rails will be considered satisfactory for equipment on cars and cranes.

(*b*) The metallic parts of portable cranes, derricks, hoists, and similar equipment on which wires, cables, chains, or other conducting objects are maintained should be provided with an effective protective ground (see sec. 9), where operated in the vicinity of supply lines operating at over 150 volts to ground, whether the cranes or similar equipment are themselves electrically operated or not.

382. Control of Energy Supply to Cars and Cranes

(*a*) Readily accessible means shall be provided whereby all conductors and equipment located in or on cars or cranes can be disconnected entirely from the source of energy at a point as near as possible to the trolley or other current collectors.

(*b*) A circuit breaker or switch, capable of interrupting the circuit under heavy loads, shall be used unless the current collector can be safely removed, under heavy loads, from the trolley or third rail.

(*c*) Where a car is operated in locations other than private rights-of-way and equipped with both trolley and third-rail current collectors, means shall be provided by which any exposed third-rail collector can be readily disconnected from the trolley circuit when not in use.

383. Control of Movement of Cars, Cranes, and Elevators

(*a*) Means shall be provided whereby the operator (whether motorman or elevator attendant) can prevent the starting of the equipment by unauthorized persons while he is absent from his post.

Removable reverse levers or controller handles and locked doors to the operator's cab are among the most effective means.

(*b*) The car-control lever of passenger elevators should be located so that the operator can readily face the principal car opening. For cars and traveling cranes the car control should be so located that the operator can readily face the direction of travel.

384. Subway and Car Lighting

Subways and similar locations used for passenger transportation where artificial illumination is indispensable shall be lighted throughout their entire length by a system independent of the current for electric traction where such is used. It is recommended that passenger cars operated in such locations and lighted normally by the current for electric traction shall be equipped with an auxiliary system of emergency lighting.

Sec. 39. TELEPHONE AND OTHER SIGNAL APPARATUS ON CIRCUITS EXPOSED BY SUPPLY LINES

390. Guarding Noncurrent-Carrying Parts

(*a*) Where telephone or other signal apparatus (not included under *b* below) which must be handled by persons is permanently connected (not including portable telephones) to overhead signal circuits exposed by supply lines over 400 volts to ground, provision shall be made by one of the following methods against shock to persons handling apparatus:

(1) The use of suitable protective devices, including fuses and arresters.

(2) The grounding of all exposed noncurrent-carrying metal parts and the suitable guarding of all ungrounded current-carrying parts. (See rule 391.)

(3) The arrangement of apparatus in such a way that persons using it will be obliged to stand on a suitably insulated platform, in a suitably insulated booth or on other insulating surfaces. (The above applies only where apparatus is accessible to none but authorized persons.)

(4) The arrangement of apparatus (on signal circuits exposed to supply lines of more than 750 volts to ground) so as to have no exposed current-carrying parts exceeding 2 square inches in area with which a person is liable to come in contact and the use of suitable protective devices, including fuses and arresters or other means.

(*b*) Such signaling devices as fire and police alarm boxes and telegraph test boxes, if connected to overhead signal circuits exposed by supply lines over 400 volts to ground, should have the accessible noncurrent-carrying metal parts permanently grounded wherever the character of service gives valid objection to the use of arresters or transformers on the signal circuit.

Police-alarm boxes, where connected to overhead police-alarm circuits, should usually be protected by arresters operating at 400 volts to ground, placed in the connecting leads outside the box.

Fire-alarm boxes connected to overhead circuits, if not protected by arresters, should be provided with suitable insulating material between the circuit within and the exposed frame and operating hook, this insulation to be capable of withstanding the highest voltage of the supply circuits to which the fire-alarm circuit is exposed up to 7500 volts.

391. Guarding Current-Carrying Parts

(*a*) Telephone or other signaling devices which are permanently located outdoors or where exposed to corrosive fumes or dampness (such as may occur in subways, cellars, basements, laundries, stables, etc.) shall be so arranged that all ungrounded current-carrying parts are so guarded as to be suitably protected against the prevailing atmospheric conditions.

The inclosing cases of signal apparatus provide suitable guards if substantially built of metal or insulating materials.

(*b*) Receiver cords shall be guarded by shields of permanently grounded metal (such as metal armor) or of nonabsorptive insulating material (such as flexible insulating tubing) or shall have suitable insulating coverings for the individual conductors.

(*c*) Where no protective device is installed (permissible only for fire-alarm or similar apparatus or for apparatus not for public use, where the character of service precludes the use of arresters and fuses) the shields of portable cords shall always be of grounded metal or of special insulating material suitable to withstand the voltage of the highest supply circuit to which the signal circuit is exposed up to 7500 volts.

392. Protection Against Induced Voltages

(*a*) All telephone or other signaling equipment which must be handled by persons and which is connected to a line that parallels a supply circuit in such manner that by reason of exposure to the supply circuit under normal operating conditions more than 150 volts are induced between the terminals of the signaling equipment and ground shall be protected by one or more of the following means:

(1) All exposed metal parts of the equipment shall be insulated from the circuit, and the circuit shall be protected by arresters having a breakdown potential not exceeding one-half that of the insulation between the above-named noncurrent-carrying metal parts and the current-carrying parts.

Cords shall have an additional insulating tubing protection.

(2) All exposed noncurrent-carrying metal parts shall be permanently grounded and all current-carrying metal parts shall either be permanently grounded or adequately shielded. (See rule 391.)

(3) All equipment shall be so located that persons coming into contact with the equipment shall be obliged to stand either on an insulated platform or in a booth of suitable insulating material.

393. Grounding of Arresters for Signaling Systems

The ground connections for outside installations of cable protectors employed solely to prevent electrical injury to the cable need not conform with the requirements of this rule. For rules governing the grounding of the metal cases of outdoor apparatus as covered by this section, see section 9.

(*a*) Arresters shall be permanently and effectively grounded in the following manner:

(1) Ground Conductor.—The ground conductor shall preferably be of copper (or other material which will not corrode under the conditions of use) and shall be not less than No. 18 in size and in urban districts or where within buildings shall be covered with a suitable insulation.

If necessary to guard the ground conductor from mechanical injury (on poles or where a ground conductor on the outside of building walls is near a roadway, sidewalk, or pathway, thus necessarily exposing it to tampering by unauthorized persons), it shall be protected for a distance of 8 feet from the ground by a wooden molding or by conduit of nonmagnetic material.

(2) Ground Connection.—The ground connection shall be made to a cold-water pipe, where available, connected to the street mains and in service. An outlet pipe from a water tank fed by a street main may be used provided such outlet pipe is adequately bonded around the tank to the inlet pipe connected to the street main.

If a cold-water pipe is not available, the ground connection may be made to a gas pipe, provided the ground conductor is attached to the pipe between the meter and the street mains.

If cold-water or gas pipes are not available, the ground connection may be made to an iron rod or pipe driven into permanently damp earth, or to a plate or other body of metal buried in permanently damp earth. (Compare rule 93.)

Steam or hot-water pipes should not be used for ground connections.

Driven rods or pipes, used as ground connections for protectors, shall not be also used as ground connections for electrical supply circuits or electrical apparatus, and where water or gas pipes are used for a ground connection, attachment to such pipes shall be made at a different point than for attachments to electrical supply circuits or equipment.

(*b*) Connecting Ground Conductor to Pipes.—Ground conductors shall be attached to pipes by means of suitable ground clamps; the entire surface of the pipe to be covered by the clamp shall be thoroughly cleaned.

(*c*) Connecting Ground Conductor to Driven Rod or Pipe.—The ground conductor shall be so attached to the rod or pipe as to give reliable connection both mechanically and electrically and in such a manner as to prevent corrosion when the joint is buried in the earth.

(*d*) Connecting Ground Conductor to Buried Electrode.—Where buried plate or other metal electrode is employed the ground conductor shall be securely fastened to it in such manner as to make a reliable electrical and mechanical contact.

DISCUSSION OF PART 3—UTILIZATION EQUIPMENT

Sec. 30. PROTECTIVE ARRANGEMENTS

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 the precautions of workmen, 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, but 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. Depending upon the character of equipment and degree of hazard involved, the rules for guarding parts at lower voltage are waived, within stated limits.

However, utilization equipment made inaccessible to all but authorized attendants frequently approximates the conditions in supply stations which are dealt with in Part I and under such conditions the less rigid requirements of those rules apply. On the other hand, any such less guarded equipment should be carefully separated from any nonelectrical processes which might seriously distract the attention of the operator, even where properly qualified for electrical work, from the necessary care in handling unguarded current-carrying parts.

301. Application of the Rules

See discussion under Part 1.

It will, in general, be found less frequently advisable to modify or waive the utilization rules than perhaps 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 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 might lead to improvements in the art. The administrative authorities under such circumstances should sufficiently 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.

302. General Requirements

See discussion on rules 110 and 202.

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 and character of load.

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.

303. Inspection and Repairs

See discussion on rule 111

The inspection of electrical utilization 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 expert observation and any electrical defects may go unnoticed and, of course, uncorrected until an accident occurs.

With some kinds of electrical equipment it is essential that cleaning be done occasionally as, for instance, with motors, especially where oil or dust may collect on windings. A periodical inspection should be given to electrical utilization equipment of all kinds. Such inspection will aid in detecting abraided 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 abraided portable cords supplying mechanical protection to wires in exposed locations and like minor matters.

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 repairs by persons not properly qualified to do such work.

304. Grounding

(*a*) See discussion on rule 113 *a*.

(*b*) The grounding of circuits as a protective measure is entirely for the purpose of preventing persons or insulation being subjected to a voltage to ground higher than the normal voltage to ground of the circuit for which it is insulated and guarded. 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 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 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 3-wire (not 3-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 3-wire circuits it is considered 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 over 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 21, 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 below 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 anywhere 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) The majority of electrical furnaces and welders use a very low voltage circuit. The insulation between these circuits and their grounded frames (see rule 351) is of low value, and small abnormal rises in voltage would break this down and automatically ground the circuit. Special grounding provisions are not necessary for such circuits, and ground connections of sufficient capacity would often be difficult to obtain.

(*c*) See discussion on 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 conduit. 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 always 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.

305. Working Space About Electrical Equipment

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 liable 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. The proper amount of working space will vary with each particular installation, and more liberal working spaces than those required in the rules will frequently be found desirable and thoroughly feasible. The installation of electrical utilization equipment after the plant has been built and other machinery set sometimes produces a crowded condition which may become dangerous if some positive minimum working distances are not strictly adhered to.

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, where feasible, 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.

306. Guarding or Isolating Live Parts

(See discussion on Rule 116.)

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.

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 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 *d*.)

307. Hazardous Locations

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.)

308. Storage Batteries, Transformers, and Lightning Arresters

(See discussion on sections 13 and 14.)

The advisability of providing a fireproof inclosure for transformers and other apparatus having considerable oil in contact with the windings is even greater with utilization equipment than in the case of stations, since the surroundings are more frequently combustible 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.

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 1000 feet or more, in locations subject to severe lightning.

309. Identification

The ability to readily identify and trace the connections of equipment not only facilitates repairs but safeguards against the danger of handling live parts in the mistaken belief that they are disconnected. 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 automatic cut-outs protecting any circuit should be labeled to show the destination and character of the circuit concerned. Where, as is usual, such automatic cut-outs are grouped in a cabinet or on a panel board, such identification often provides the principal means for tracing the connections of the installation.

Sec. 31. CONDUCTORS

310. Electrical Protection

For the best protection of persons in the vicinity of or engaged in operating switches, the conductors of the circuit concerned 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 the insulating coverings of the conductors.

Neutral conductors should not be interrupted unless outer conductors are disconnected at the same time, since this might result in an unbalancing of the load and the subjection of equipment and operators to nearly double the designed voltage.

In general, double fuse protection in the final circuits to equipment or devices is necessary to provide sufficient assurance against the explosion or failure of fuses under severe short circuits. See "Investigation on Inclosed Fuses" by the Bureau of Standards (Tech. Paper No. 74).

A grounded conductor should never be interrupted by the opening of an automatic cut-out between the source of supply and the ground wire, since this would permit the entire circuit to lose its ground connection and possibly to assume the voltage and hazard of any circuit by which it is exposed and from which leakage might therefore occur. (See discussion on rule 92 *a*.)

313. Guarding Conductors

Inclosing conductors in suitable inclosures, of insulating material or grounded metal, provides one of the most effective means for guarding persons from contact with them.

314. Guarding in Damp or Hazardous 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 very low voltages, since the deterioration of insulation and the danger from even slight leakage is considerable. If such conductors are not in grounded conduit, the only effective protection will 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 reduce leakage to a minimum. For conductors in locations where inflammable gas exists, see discussion on rule 154.

318. Grounding or Isolating Service Conduits

(*a*) Service conduits from overhead lines are subject to occasional leakage from the contained conductors, due to breakdowns. While considered safer to persons if grounded, the guarding of exposed service conduits for a distance of at least 8 feet from the ground, or floors accessible to the public, is considered to afford reasonable safety where the protective ground connection is *not* provided. Underground service conduits are easily grounded and frequently contain grounded metal-sheathed cable, thus making unnecessary any other ground.

(*b*) When conduit containing service conductors on the supply side of service cut-outs is not directly and permanently grounded, it should not be allowed to be in contact with metal of interior conduits or with metal parts of the building. This is because the interior conduits or the metal parts of the building, such as metal awning frames or metal sidings, may not be sufficiently well grounded to prevent their being raised to a dangerous potential by contact with an ungrounded or poorly grounded service conduit. Cases have occurred where small ground connections to conduit within the building have been burned or broken off. Therefore, either the very thorough and direct grounding of the service conduit, or its careful insulation from the interior conduit and from the building framework, together with its isolation from persons in the vicinity, are required for safety.

319. Temporary Wiring

The tendency to install unsubstantial wiring with the purpose of soon correcting the defects is responsible for the existence of much defective wiring in present equipment. Such "temporary" wiring often remains for years, presenting a serious menace to operators and service, whereas the additional cost and time required to make the installation substantial would have been inconsiderable.

Sec. 32. FUSES AND OTHER CUT-OUTS, SWITCHES, AND CONTROLLERS

320. Accessible and Indicating

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 tends toward 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 resistances for certain types of equipment are cut out of circuit.

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.

321. Hazardous Locations

See discussion on rule 161.

322. Where Switches are Required

See discussion on rule 162.

323. Character of Switches and Disconnectors

A frequent cause of accidents has been through an attempt to interrupt large currents by switches incapable of safely breaking the circuit. 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 load it may be expected to carry, 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 on rule 164.)

Small switches and single pole switches, even 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.

324. Disconnection of Fusible Cut-Outs Before Handling

There are now many switch and cut-out combinations on the market contained in cabinets, which comply with the requirement given for circuits over 150 volts to ground, in that the fuses are not accessible until the switches are opened. The switch and fuses are also sometimes combined in a single device. As it is very probable that fuses protecting motors, and other fuses which are frequently blown, must be replaced by uninstructed persons or those whose principal attention must be given to the machinery driven, the use of such switch and cut-out combinations will, in the near future, be generally extended to many industrial installations operating at 110 to 130 volts to ground. With the larger-size fuses this is particularly desirable, as many persons are annually burned or shocked while replacing fuses in live terminals.

Current practice in panel board design is still to have the current-carrying parts exposed during operation, although generally inclosed by the cover of the cabinet at other times. Some panel board manufacturers are now, however, producing "dead face" panels which have the same safety features as the switch and cut-out combinations referred to above. (See discussion on rule 166.)

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, etc., 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 of Switches and Automatic Cut-Outs

(*a*) Switches are now marketed in increasing numbers to meet the demand for a switch which may be quickly handled with entire safety to an operator, because all live or arcing parts are entirely inclosed during operation. It is, however, possible to greatly reduce the chance of injury attendant upon operation of open switches by use of shields so arranged as to cover the switch blades (and live crossbar screws) while the latter are closed. In some cases no complete shield is provided, but the switch blades are, when closed and so made alive, depressed below an insulating surface, and no live part can therefore be touched, although some danger from arcing may still remain. (See discussion on rule 169.)

Sec. 33. SWITCHBOARDS AND PANEL BOARDS

330. Accessibility and Convenient Attendance

See discussion on rule 170.

331. Location

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 switchboard space, by means of a substantial guard rail, affords the much-needed protection to the switchboard itself as well as to the operator.

335. Guarding Current-Carrying Parts

(*a*) 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 only 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 larger 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 albarene stone, soapstone, slate, and marble, are satisfactory if having no conducting veins.

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 surface.

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.

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 interference. No consideration seems to warrant having switchboards placed where they would be accessible to the general public or to employees of factories 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 are thus often present warranting 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, busses, and terminals being inclosed in locked compartments.

(*b*) 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. 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.

(*c*) "Dead-face" panel boards have been much used abroad, but their use has only recently become extensive in this country. For theater-stage switchboards, however, with the attendant panic hazards, 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, nearly 30 theaters being exclusively equipped in this manner, thus providing correspondingly greater safety to their audiences.

Sec. 34. MOTORS AND MOTOR-DRIVEN MACHINERY

340. Control Devices

(*a*) The importance of automatic speed-limiting devices for use with certain types of motors and converters is becoming better realized by users. Centrifugal devices are generally used, which operate relays actuating switches in the motor-supply circuits. Motor-generators and rotary converters when operating 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. Such loads as direct-connected fans, pumps, or loads of the same character driven through positive mechanical connections such as are provided by gear or chain drives, which are free from the danger of releasing the motor, due to belts slipping off, obviate the necessity for speed-limiting devices.

(*b*) 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. 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 "no-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.

343. Guards for Live Parts

For low-voltage machines guarding is sometimes accomplished by use of insulating mats. These prevent the most frequent cause of shocks, 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, caused by bringing the body in contact with grounded parts while touching live parts, 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, and with utilization equipment of the higher voltages this precaution should generally be taken even in relatively dry and clear spaces.

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 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, therefore, feasible to inclose the motor in a fenced space accessible only to qualified inspectors or repair men. The less rigid rules for stations then apply to such motor installation. (See rules 123 and 125.)

344. 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 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 jurisdiction.

Sec. 35. ELECTRIC FURNACES AND WELDERS

350. Protection from Burns

The shielding of the eyes and unclothed body surfaces from the intense radiation 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 strains 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 the ultra-violet and infra-red rays. The use of a suitable headgear other than goggles sometimes is necessary to protect the face. 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.

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 permit.

351. Grounding

Where furnaces and welders 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 lower 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 serious short circuits.

For parts over 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 usually be confined to lower voltages.

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 advantage to 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 advisable. This is especially necessary when surrounding atmosphere is damp, as in baths, laundries, stables, breweries, 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 ground wire may be necessary. Grounding by means of a grounded conductor where this runs to the fixture has been sometimes recommended, but may in many cases be inadvisable, as introducing different voltages on different exposed fixtures and connected piping systems in the building, which may in turn produce unexpected currents in dangerous locations. The grounding of fixtures in this manner may be found practicable, however, when the fixture is not touching or in close proximity with metal ceiling, metal lath, gas piping, metal reinforcement of buildings, or similar conducting material which may introduce large currents in the grounded conductor of the circuit, or produce arcing at this or other points by reason of their discontinuous arrangement. Usually, however, grounding to neighboring water, heating, or other piping systems (except gas) will be feasible, and provide an effective and desirable protective connection.

The grounding in case of combination gas and electric fixtures presents a peculiar problem. Gas piping is sometimes practically discontinuous by reason of comparatively high resistance joints. Its repair is carried on regardless of electrical considerations. 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 even distinctly bad practice where no other ground is available for the fixture. The grounding of fixtures not insulated from gas piping, by means of a circuit conductor necessarily having a potential drop, is considered very inadvisable.

Combination fixtures and the proximity of gas pipes to electric conductors should be avoided wherever practicable, from both life and fire hazard viewpoints.

361. Insulation

In the past, one defect of fixtures has been their inability to withstand in actual service the voltage between live parts within and the external metal shell. This weakness has existed in fixture stems with the conductor insulating covering and in sockets with the insulating lining. It has been constantly urged as a reason for not grounding the outer shell, although the absence of ground has meant more or less frequent leakage from one live part within to the outside casing and occasional injury or fatality to persons from contact. A fair solution of this problem seems to be the requirement that fixtures withstand under service conditions a suitable breakdown test from live parts to outer casing, and have exterior metal grounded as required by the preceding rule.

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 much metallic piping or plumbing liable to be grounded. The frequent slight grounds of electrical circuits at other places makes it possible to establish a circuit between the exposed live parts and the piping. In some instances ordinary lighting circuit voltages are sufficient to cause death, particularly in damp laundries, bathrooms, and similar places.

By identifying circuit conductors as is thoroughly practicable, and now done in Providence, R. I., it becomes easy to fix the inner screw shell of all sockets and receptacles at approximately ground potential, reducing the probability of breakdown from the inner screw shell to the external metal of the socket, and preventing the danger otherwise present, that persons will touch the ungrounded screw lamp base and at the same time the grounded outer casing.

363. Accessibility and Guarding of 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.

366. Isolating or Guarding Lamps in Series Circuits

Series circuits are, in general, very objectionable in buildings or in spaces accessible to the general public. Even on poles out of ordinary 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.

Even the supporting or lowering devices for lamps on poles or on span wires deserves 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.

Sec. 37. PORTABLE DEVICES, CABLES, AND CONNECTORS

370. Insulation

In most portable devices 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 necessary for the dielectric depends on the uses and the location. Treated wood fiber may be satisfactory where the conditions 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 devices, 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

The grounding of external metal parts of portable devices is no less to be recommended as a safety measure than the grounding of lighting fixtures and other fixed devices. Indeed, the fact that portable devices are more handled, and may be carried into close proximity to plumbing and similar grounded surfaces, makes their grounding even more desirable. With portable devices, however, the grounding can be accomplished only through a portable ground wire. To protect this properly, while securing at the same time sufficient flexibility, is a problem which has been solved in other countries and for some devices in this country, by the use of identified conductors in the portable cable, the one used as ground wire to be used only for this protective purpose, and not also for normal current carrying.

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 be made only to *recommend* grounding, and to emphasize the especial need for such protection for portables on circuits over 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 connectors arranged for grounding should permit the absence of this protection.

372. Cable Connectors

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.

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 ground 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 ground wire (a third wire with two conductor cables) makes mistakes very unlikely. The ground terminal on each side of the separable connectors should be no less distinctly marked.

374. Use of Portables and Pendants

Most engineers discourage the use of portable attachment cords in any locality, because of their liability to become mechanically damaged and because of the tendency toward their continued use after they become very unsafe by lack of insulation. Many devices, however, are necessarily portable and portable cords must be used.

Limitations for their use are therefore difficult to set, and at low voltages the use of portable devices and cords does not necessarily present serious life hazard. The rule, as given, indicates the cautions which should be observed where use of cords is necessary. In many car houses special low voltage circuits are run in car pits and other places where the use of some kind of a portable light is necessary, to avoid the extra danger by use of the relatively high voltage trolley circuit.

Sec. 38. ELECTRICALLY OPERATED CARS, CRANES, AND ELEVATORS

380. Guarding Live and Moving Parts

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 cutouts (circuit breakers and others) so that flashes will not burn persons is now receiving more attention than formerly.

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 other cases, to obviate the necessity for emergency lights in individual cars, sufficient illumination is provided for the entire subway from two sources, one being automatically switched on when the other fails.

Sec. 39. TELEPHONE AND OTHER SIGNAL APPARATUS ON CIRCUITS EXPOSED BY SUPPLY LINES

390. Grounding Noncurrent-Carrying Parts

(*a*) 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 strains 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 omission of the 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*) 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 signaling 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 signaling 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 predominantly electrostatic for the types of circuit ordinarily used. The voltage limit of 150 volts is about the maximum which would be induced electrostatically by a balanced nontransposed 6600-volt circuit in signaling circuits on the same pole line 6 feet away. It is approximately that which would be induced by a 30 000 to 50 000 volt nontransposed supply circuit in a signaling circuit paralleling it at a distance of 50 feet, unless this circuit were partly shielded by the presence of other wires. In cases in which the signaling circuit does not parallel the supply circuit for the entire distance, the induced voltage is reduced by the effect of those portions of the signaling circuit remote from the supply circuit.

Frequently the transposition of conductors in a metallic return supply circuit will assist materially in preventing induced voltages over 150 to ground on neighboring signal circuits.

393. Grounding of Arresters for Signaling 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; and 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

CONTENTS

SCOPE

The safety rules in sections 40–54 apply to the operation of, and work on or about, supply lines and signal lines used in connection therewith, and to the operation of and work on or about the electrical equipment of central stations, substations, private plants, and on or about electrical tests, and tunnel, subway, or similar underground work. They do not apply to new construction, which has not been made available for regular service.

While all the rules find application in the larger industrial or private plants and in moderate-sized utilities, some do not apply (or apply less fully) in the smaller. It has seemed unwise, however, to attempt to restrict the scope of these rules to rules which are applicable to all organizations or to all classes of electrical work.

The safety rules in sections 55–58 apply to commercial telephone, telegraph, and other signal equipment and lines, with terminology adapted to the special needs of the employees concerned.

RULES FOR THE EMPLOYER

Sec. 40. ORGANIZATION

400. Interpretation and Enforcement of Rules

(*a*) The employer shall furnish to each regular employee operating or working on electrical supply equipment, supply or signal lines, or hazardous electrical tests a copy of these safety rules for operation (or such of these rules as apply to his work), either separately or incorporated in more comprehensive rule books, and shall take means to secure the employee's compliance with the same.

(*b*) If a difference of opinion arises with regard to the meaning or application of these rules or as to the means necessary to carry them out, the decision of the employer or his authorized agent shall be final, subject to an appeal (if taken) to the regulative body having jurisdiction.

(*c*) Cases may arise where the strict enforcement of some particular rule will seriously impede the progress of the work in hand; in such cases the employee in charge of the work to be done and the employee in charge of that portion of the system on which the work is to be done may, with the consent of the chief operator concerned, make such temporary modification of the rule as will expedite the work without materially increasing the hazard.

(*d*) Many companies number their books of rules and require a receipt from each employee for his copy.

401. Organization Diagram

To better secure the safe and accurate performance of work, an organization diagram or written statement clearly showing the division of responsibility between officials and employees, down to and including the grade of foreman, should be supplied with the book of rules, or the rules should be posted conspicuously in offices and stations of the employer and in other places where the number of employees and the nature of the work warrants.

402. Address List and Emergency Rules

The rule book should contain or be accompanied by the following:

A list of names and addresses of those physicians and members of the organization who are to be called upon in emergencies.

A copy of rules for first aid, resuscitation, and fire extinguishment.

These should also be kept in conspicuous locations in every station and testing room, in line wagons, and in other places where the number of employees and the nature of the work warrants.

403. Instructing Employees

Employees regularly working on or about equipment or lines shall be thoroughly instructed in methods of first aid, resuscitation, and where advisable in fire extinguishment.

404. Qualifications of Employees

The employer shall use every reasonable means and precaution to assure himself that each employee is mentally and physically qualified to perform his work in accordance with these rules.

405. Chief Operator

(*a*) A properly qualified chief operator, system operator, load dispatcher, general superintendent, or otherwise designated employee, whose duties shall be those prescribed in rule 430, shall be in charge of the operation of electrical equipment and lines and directly responsible for their safe operation.

(*b*) In large organizations the duties of the chief operator may be delegated for any particular section of the system to a deputy chief operator (or otherwise designated employee) who shall report as required to the chief.

(*c*) When it is impracticable to have the entire system placed in charge of one chief operator, the duties of the chief operator may be performed for a portion of the system by a local superintendent, local manager, or other employee who may also perform other duties.

(*d*) In small organizations the duties of the chief operator may be performed by the superintendent, electrician, engineer, or some other employee who may also perform other duties.

In these rules the various employees listed by above titles, including the deputy chief operator, will be designated (for simplicity) by the title of chief operator, where referred to in this capacity.

406. Responsibility

If more than one person is engaged in work on or about the same electrical equipment or lines at any one location, one of the persons shall be designated as the foreman locally in charge of the work; or all of the workmen shall be instructed as to the work they are to perform, and the employee instructing the workmen shall be considered in charge of the work.

Sec. 41. PROTECTIVE METHODS AND DEVICES

410. Attendance

Unless a qualified employee is kept on duty where generators or rotary converters are operating, such equipment shall be made inaccessible to unauthorized persons.

411. Requirement for Two Workmen

Except in trouble or emergency work, at least two employees should be provided where work is done on live lines above 750 volts in wet weather or at night.

412. Uninstructed Workmen and Visitors

Unqualified employees or visitors shall be prohibited from approaching any live parts, unless accompanied by a qualified employee.

413. Diagrams for Chief Operator

Diagrams or equivalent devices, showing plainly the arrangement and location of the electrical equipment and lines, should be maintained on file or in sight of the chief operator.

These diagrams may be of the entire system, of each specific portion of the system, or they may show typical arrangements.

414. Instructions to Employees

All employees shall be instructed as to the character of all equipment or lines on or dangerously near to which, work must be done by them.

Instructions shall describe the equipment and lines to be worked on, identifying them by position, letter, color, number, or name.

415. Protective Devices

There shall be provided in conspicuous and suitable places in electrical stations, testing departments, and line construction and repair wagons a sufficient supply of suitable protective, first-aid, and fire-extinguishing devices and equipment, to enable employees to meet the requirements of these rules. Such devices and equipment shall be inspected or tested to insure that they are kept in good order. The following is a list of suitable devices and equipment, the kinds and numbers of which will depend on the requirements of each case:

(1) First-aid outfits.

(2) Insulating wearing apparel, such as insulating gloves, sleeves, and boots. Insulating shields, covers, mats, stools, and platforms. Insulating appliances, such as rods and tongs, for any necessary handling or testing of live equipment or lines.

(3) Protective goggles of suitable materials and construction.

(4) Tools of such special design and insulation as to eliminate so far as practicable the danger of forming short circuits across conducting parts at different potentials or bringing the user into circuit with such parts.

(5) "Men at Work" tags, log books, operating diagrams or equivalent devices, and portable danger signs.

(6) Fire-extinguishing devices, either designed for safe use on live parts or plainly marked that they must not be so used.

(7) Grounding devices for making protective grounds.

Safety belts, whether furnished by employer or employee, should be inspected from time to time to assure that they are in safe working condition.

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416. Warning and Danger Signs

There shall be displayed in conspicuous places at all unattended and unlocked entrances to electrical supply stations, substations, and testing rooms containing exposed current-carrying parts or moving parts, permanent warning signs forbidding entrance to unauthorized persons.

Suitable danger signs shall be placed in supply stations, substations, switching towers, and testing rooms about equipment having exposed current-carrying parts above 750 volts.

GENERAL RULES FOR THE EMPLOYEE

Sec. 42. GENERAL PRECAUTIONS

420. Rules and Emergency Methods

The safety rules should be carefully read and studied. Employees may be called upon at any time to show their knowledge of the rules.

Employees should familiarize themselves with approved methods of first-aid, resuscitation, and fire extinguishment.

421. Heeding Warnings, Warning Others

Employees whose duties do not require them to approach or handle electrical equipment and lines should keep away from such equipment or lines.

They should cultivate the habit of being cautious, heeding warning signs and signals, and always warning others when seen in danger near live equipment or lines.

422. Inexperienced or Unfit Employees

No employee shall do work for which he is not properly qualified on or about live equipment or lines, except under the direct supervision of an experienced and properly qualified person.

423. Supervision of Workmen

Workmen whose employment incidentally brings them in the neighborhood of electrical supply equipment or lines with the dangers of which they are not familiar shall proceed with their work only when authorized. They shall then be accompanied by a properly qualified and authorized person, whose instructions shall be strictly obeyed.

424. Exercising Care

Employees about live equipment and lines should consider the effect of each act and do nothing which may endanger themselves or others. Employees should be careful always to place themselves in a safe and secure position and to avoid slipping, stumbling, or moving backward against live parts. The care exercised by others should not be relied upon for protection.

425. Live and Arcing Parts

(*a*) Treat Everything as Alive.—Electrical equipment and lines should always be considered as alive, unless they are positively known to be dead. Before starting to work, preliminary inspection or test should always be made to determine what conditions exist. (See rules 440 and 461.)

(*b*) Protection Against Arcs.—If exposed to injurious arcing, the hands should be protected by insulating gloves and the eyes by suitable goggles or other means.

Employees should keep all parts of their bodies as distant as possible from brushes, commutators, switches, circuit breakers, or other parts at which arcing is liable to occur during operation or handling.

426. Safety Appliances and Suitable Clothing

(*a*) Safety Appliances.—Employees at work on or near live parts should use the protective devices and the special tools provided, first examining them to make sure that these devices and tools are suitable and in good condition. Protective devices may get out of order or be unsuited to the work in hand.

(*b*) Suitable Clothing.—Employees should wear suitable clothing while working on or about live equipment and lines. In particular they should keep sleeves down and avoid wearing unnecessary metal or inflammable articles, such as rings, watch or key chains, or metal cap visors, celluloid collars or celluloid cap visors. Loose clothing and shoes that slip easily should not be worn near moving parts.

427. Safe Supports and Safety Belts

(*a*) Safe Supports.—Employees should not support themselves on any portion of a tree, pole structure, scaffold, ladder, or other elevated structure without first making sure that the supports are strong enough, reinforcing them if necessary.

Portable ladders should be in a safe position before being climbed. The slipping of a ladder at either end should be carefully guarded against, especially where the surfaces are smooth or vibrating.

(*b*) Safety Belts.—Employees should not work in elevated positions unless secured from falling by a suitable safety belt or by other adequate means. Before an employee trusts his weight to the belt, he should determine that the snaps or fastenings are properly engaged and that he is secure in his belt. Any employee who furnishes his own belt shall from time to time submit it to his employer for inspection.

428. Fire Extinguishers

Employees should avoid using fire extinguishing liquids which are not insulating in fighting fires near exposed live parts. If necessary to use them, all neighboring equipment should first be killed. (See sec. 45.)

429. Repeating Messages

To avoid misunderstandings and to prevent accidents, each person receiving an unwritten message concerning the handling of lines and equipment shall immediately repeat it back to the sender and secure his full name and acknowledgment. Each person sending an unwritten message shall require it to be repeated back to him by the receiver and secure the latter's full name.

Sec. 43. GENERAL OPERATION

430. Duties of Chief Operator

The chief operator, described in rule 405, shall keep informed of all conditions affecting the safe and reliable operation of the system, and shall keep a suitable record or log book showing all changes in such conditions. He shall read and sign such record when assuming duty and sign again on being relieved. He shall keep within sight operating diagrams or equivalent devices indicating whether electrical supply circuits are open or closed at stations under his immediate jurisdiction and where work is being done under his special authorization, provided that these devices shall not be required for any chief operators classed under paragraphs (*c*) and (*d*) of rule 405 if the record or log sheets show these conditions.

His further duties will vary according to the size and character of the system under his jurisdiction, and might, for example, be about as follows:

(1) In the case of distribution from a single station, he shall direct the starting and stopping of generating equipment and the opening and closing of outgoing circuits. He shall, in general, give permission for work to be done on live lines above 7500 volts and in all cases where circuits are killed at the station for the protection of workmen.

(2) In the case of a system consisting of one or more generating stations and a number of substations, he shall have supervisory charge within his jurisdiction of the operation of all generating

and substation equipment and direct charge of interconnected transmission and feeder lines, and where protection of workmen is concerned, shall direct the starting and stopping of generating and substation equipment. He shall, in general, give permission for work on live lines above 7500 volts and on live interconnected lines, and in all cases where circuits are killed at the generating stations for the protection of workmen.

In these rules the person performing these duties is designated as chief operator, regardless of his ordinary title.

431. Duties of Foreman

(*a*) Each foreman in charge of work shall adopt such precautions as are within his power to prevent accidents and to see that the safety rules are observed by the employees under his direction. He shall make all the necessary records, reporting to his chief operator when required. He shall, as far as possible, prevent unauthorized persons from approaching places where work is being done. He shall also prohibit the use of any tools or devices unsuited to the work in hand or which are so defective or in such poor condition as to make them unsafe.

(*b*) The qualified persons accompanying uninstructed workmen or visitors near electrical equipment or lines shall take precautions to provide suitable safeguards and see that the safety rules are observed.

432. Special Authorizations

(*a*) Special Work.—Special authorization from the chief operator shall be secured before work is begun on or about station equipment, transmission, or interconnected feeder lines or live lines above 7500 volts, and in all cases where lines are to be killed by regular procedure (see sec. 45) at stations, and a report shall be made to him when such work ceases.

Exceptions.—In emergency, to protect life or property, or when communication with the chief operator is difficult, due to storms or other causes, any qualified employee may make repairs on or about the equipment or lines covered by this rule without special authorization if the trouble is such as he can promptly clear with help available in compliance with the remaining rules. The chief operator shall thereafter be notified as soon as possible of the action taken. (See rule 436 *b*.)

(*b*) Operations at Stations.—In the absence of specific operating schedules for opening and closing supply circuits at stations, or starting and stopping equipment, employees shall secure special authorization from the chief operator before performing these operations. In all cases such special authorization shall be secured where circuit or equipment control devices are tagged at stations to protect workmen. (See rule 435.)

Exceptions.—In emergency, to protect life or property, any qualified employee may open circuits and stop moving equipment without special authorization if, in his judgment, his action will promote safety, but the chief operator shall be notified as soon as possible of such action, with reasons therefor. To maintain service, any qualified employee may also reclose circuits which have been opened by automatic cut-outs, except where this is prohibited by rule.

(*c*) [illegible]ING OUT SECTIONS OF CIRCUITS.—Special authorization shall be secured from the chief operator before sections of overhead or underground circuits are cut off by employees at points other than at stations by means of sectionalizing switches.

Exception.—Portions of distribution circuits below 7500 volts may be cut off by authorized employees, without special authorization from the chief operator, by means of sectionalizing switches, if the chief operator is thereafter notified as soon as possible of the action taken. This may also be done even for circuits above 7500 volts when communication with the chief operator is difficult.

433. Restoring Service After Work

No instructions for making alive equipment or lines which have been killed by permission of the chief operator to protect workmen shall be issued by him until all workmen concerned have been reported clear. When there is more than one workman at a location, a person authorized for the purpose shall report clear for such workmen, but only after all have reported clear to him. If there is more than one gang, each shall be so reported clear to the chief operator.

434. Maintaining Service

(*a*) When live circuits on which "Men at work" tags have been placed are opened automatically, they should be kept disconnected until the chief operator has given proper authorization for reconnection.

(*b*) When overhead circuits other than trolley and third-rail circuits open automatically, the employer's local operating rules shall determine in what manner and how many times they may be closed with safety for persons on or near those circuits. The chief opertor shall be advised of the conditions.

(*c*) When circuits feeding supply lines become accidentally grounded, they shall be tested to determine where the ground exists. If the ground can not be definitely located and removed by the station operator, an immediate report of the finding shall be given to the chief operator, who shall order a patrol of the lines affected to definitely locate and remove the ground as soon as practicable.

Above 7500 volts it will usually be found advisable to disconnect the circuit or effectively ground the accidentally grounded conductor until the lines have been cleared of the accidental ground.

435. Tagging Electrical Supply Circuits

Before work is done under special authorization of the chief operator on or about any equipment or lines used as transmission or interconnected feeder lines, or lines operating above 7500 volts, or lines killed at stations or substations to protect workmen, the chief operator shall have "Men at work" tags attached at all points where such equipment or lines can be manually controlled by regular operators to plainly identify the circuits worked on.

Before work is done on or about any equipment or lines which are killed by authorized employees at points other than at stations, the employees shall have "Men at work" tags placed at all points where the circuit has been disconnected to identify the portion worked on.

436. Protecting Traffic

(*a*) Barrier Guards.—Before engaging in such work as may endanger traffic, employees shall first erect suitable barrier guards. They shall also display danger signs or red lamps from two sides of the barrier at right angles to the direction of the traffic. Where the nature of work and traffic requires it, a man shall be stationed to warn passers-by while work is going on.

(*b*) Crossed or Fallen Wires.—When any crossed or fallen wires which may create a hazard are found, the employee shall remain on guard or adopt other adequate means to prevent accidents and have the chief operator notified. If the employee can observe the rules for handling live parts by the use of insulating appliances, he may correct the condition at once. Otherwise he shall first secure the authorization from the chief operator for so doing. (See rule 432 *a*.)

437. Protecting Workmen by Disconnectors

When equipment or lines are to be disconnected from any source of electrical energy, for the protection of workmen, the operator shall first open the switches or circuit breakers designed for operation under load, and then the air-break disconnectors, when provided.

Sec. 44. HANDLING LIVE EQUIPMENT AND LINES

In all these operating rules "voltage" means in general the highest effective voltage between the conductors of the circuit concerned, except that in grounded multi-wire circuits, not exceeding 750 volts between outer conductors, it means the highest effective voltage between any wire of the circuit and the ground.

In ungrounded low-voltage circuits, "voltage to ground" means in these rules the voltage of the circuit.

When one circuit is directly connected to another circuit of higher voltage (as in the case of an autotransformer), both are considered as of the higher voltage, unless the circuit of the lower voltage is permanently grounded. Direct connection implies electrical connection as opposed to connection merely through electromagnetic or electrostatic induction.

Signal equipment and lines not over 400 volts are not considered alive, except where made alive by leakage from supply equipment or lines. They are, however, a source of danger when near live supply lines, due to their liability of being grounded.

440. General Requirements

(*a*) Touching Live Parts.—No employee should touch with bare hands at the same time two parts at different potential; nor should he touch with bare hands even a single exposed ungrounded live part at a dangerous potential to ground unless he is insulated from other conducting surfaces, including the ground itself, and stands on insulating surfaces.

(*b*) Wire Insulation.—Employees should not place dependence for their safety on the insulating covering of wires.

All precautions in this section for handling live parts shall be observed in handling insulated wires.

Insulation on a wire may look perfect, but it frequently can not be relied on to prevent shock.

(*c*) Exposure to Higher Voltages.—Every employee working on or about equipment or lines exposed in overhead construction to voltages higher than those guarded against by the safety appliances provided should as far as practicable assure himself that the equipment or lines worked on are free from dangerous leakage or induction or have been effectively grounded.

(*d*) Cutting Into Insulating Coverings of Live Conductors.—When the insulating covering on live wires or cables must be cut into, the emplovee should use a suitable tool. While doing such work it is recommended that suitable goggles be worn to protect the eyes and insulating gloves to protect the hands.

When metal sheathing must be removed from cables it should be done with special tools which will not injure the insulation. The sheathing should be so cut as to leave enough exposed insulation after the conductor has been bared to avoid arcing over between the conductor and the sheath. If the cable consists of more than one conductor, similar exposed insulating surface should be left for each conductor, using insulating separators between conductors, if necessary.

Insulating devices, such as wood separators, etc., should be examined to eliminate conducting dust or chips, sharp edges or nails, which may defeat the purpose for which the devices are intended.

441. Voltages Between 750 and 7500

No employee should go or take any conducting object within six inches of any exposed live part whose voltage exceeds 750, in stations, testing rooms, in underground construction, or in overhead construction, where it is practicable to avoid this, except as follows:

(*a*) In dry locations this distance may be less than six inches, if insulating devices, such as shields, covers, or gloves are placed between the person and the part or object.

The distance may also be reduced if insulating barriers (such as mats, stools, or platforms) are placed between the person and the ground, and suitable insulating shields between the person and all other conducting surfaces, except the live part, which he could accidently touch at the same time.

(*b*) In all damp or dark locations, and wherever grounded surfaces are exposed, the distance may be less than six inches only if insulating devices are used between the person and the live parts and also between him and all other conducting surfaces with which he might otherwise come in contact at the same time.

Where safe distance from live parts can not be secured by use of the special insulating tools and appliances furnished, properly tested insulating gloves and sleeves map serve as the sole portable insulating devices between the person and live parts.

Care should be exercised in using insulating gloves to avoid puncturing them on sharp edges, especially in making wire splices. It is sometimes advisable to wear protecting gloves over insulating gloves.

442. Voltages Above 7500

No employee should go, or take any conducting object, within the distances named below from any exposed live part at or above the voltage specified, except as permitted by this rule.

Operating voltage:	Distance in feet.
7 500	1
15 000	2
50 000	3
70 000	5

Distances for intermediate voltages to be determined by interpolation.

(*a*) In dry locations these distances may be reduced, if suitable insulating guards or barriers are placed between the person and such part or object.

(*b*) If the part is being directly worked on, the tools or other mechanical appliances used shall provide the full distance of insulating material, unless protective guards are also used between the person and the live part. These protective guards may be permanent insulating covers or shields, or may be disks of insulating material, suitable for the voltages to be handled and for the attendant conditions, attached to the handles of rods or tools.

443. Requirement for Two Workmen

Except in trouble and emergency work, no employee shall work alone dangerously near live lines above 750 volts in wet weather or at night.

444. When to Kill Parts

No employee shall approach or willingly permit others to approach any exposed ungrounded part normally alive, except as provided in rules 440, 441, and 442 of this section, unless he has first assured himself of his own safety and the safety of those working under his direction by having the supply equipment and lines killed. (See sec. 45.)

445. Operating Switches and Working from Below

(*a*) Opening and Closing Switches.—Manual switches and disconnectors should always be closed by a single unhesitating motion, and, if possible, with one hand. Care should be exercised in opening switches to avoid causing serious arcing.

(*b*) Work From Below.—Employees should avoid working on equipment or lines from any position by reason of which a shock or slip will tend to bring the body toward exposed live parts. Work should therefore generally be done from below, rather than from above.

446. Attaching Connecting Wires and Grounds

(*a*) Handling Connecting Lines.—In connecting dead equipment or lines to a live circuit by means of a connecting wire or device, employees should first attach the wire to the dead part before attaching it to the circuit. When disconnecting, the live end should be removed first.

Loose conductors shall be kept away from exposed live parts.

Metal measuring tapes, and tapes, ropes or hand lines having metal threads woven into the fabric, should not be used near exposed live parts.

Ladders reinforced by metal in a longitudinal direction should not be used near exposed live parts.

(*b*) Applying Grounds.—In applying a grounding device to normally live parts the device shall be grounded before being brought near the parts, and shall be removed from the live parts before being removed from the ground connection.

447. Handling Series Circuits

Secondaries of current transformers to meters or other devices, should not be opened when alive, until a jumper has been connected across the point of opening or said secondary has been short circuited elsewhere.

Before working on arc lights or similar devices connected to series circuits they shall be short circuited, or (when necessary to avoid hazard) disconnected entirely from such circuits by absolute cut-outs.

448. Stringing Wires

In stringing wires near live conductors, they should be treated as alive unless they are effectively grounded.

Sec. 45. KILLING SUPPLY EQUIPMENT AND LINES

Where workmen must depend on others for operating switches to kill circuits on which they are to work, or must secure special authorization from the chief operator before themselves operating such switches, the following precautionary measures shall be taken in the order given, before work is begun on or about the equipment or lines concerned, as a means for preventing misunderstanding and accident.

In small organizations the chief operator may himself operate the switches and disconnectors instead of instructing others to do so, thus much simplifying and abbreviating the procedure. In certain cases the chief operator may direct the workman who wishes the section killed for his own protection, to operate some or all switches necessary himself, thus also abbreviating the procedure.

In cases where there is no station with regular attendants at either end of a section of line to be killed for the protection of workers, the rules below need not apply for disconnection of that end of the section concerned, provided that the employee under whose direction that end of the section is disconnected is in sole charge of the section and of the means of disconnection employed or that the point of disconnection at that end of the section is suitably tagged before work proceeds.

450. Workman's Request

The workman in charge of the work shall apply to the chief operator to have the particular section of equipment or lines killed, identifying it by position, letter, color, number, or other means.

451. Opening Disconnectors and Tagging

The chief operator at his discretion shall direct the proper persons to open all switches and air-break disconnectors through which electrical energy may be supplied to the particular section of equipment and lines to be killed and shall require such person to tag such switches and disconnectors, and each tag shall be of a distinctive character indicating that men are at work. All oil switches and remotely controlled switches should also be blocked where necessary for avoiding mistakes.

The person shall, when placing the tag, record the time of disconnection, his own name, the name of the workman who requested the disconnection, and the name of the chief operator.

Where the section of equipment or lines can be made alive from two or more sources, all such sources shall be disconnected. This will apply to work on lines with more than one station, also sometimes to work on transformers in banks, rotary converters, motor generators, switches, and on other similar equipment.

452. Station Protective Grounds

When all the switches and disconnectors designated have been opened, blocked, and tagged in accordance with rule 451 the chief operator shall require each person operating them to make protective grounds (see section 46) upon the lines being killed and to report to him when such grounds are in place.

453. Permission to Work

Upon receipt of information from all persons operating switches and disconnectors that protective grounds are in place the chief operator shall advise the workman who requested the killing of the section that the specified section of equipment or line has been killed and that he may proceed to work.

454. Workmen's Protective Grounds for Overhead Lines

The workman in charge should immediately proceed to make his own protective grounds on the disconnected lines, except under conditions where the making of such grounds will itself be more hazardous than working on the lines without grounding. Such grounds shall be made between the particular point at which work is to be done and every source of energy.

455. Proceeding with Work

After the equipment or lines have been killed (and grounded, if required by rule 454), the workman in charge and those under his direction may proceed with work without taking the precautions required on or about live parts by these rules.

456. Procedure for Other Gangs

Each additional workman in charge desiring the same equipment or lines to be killed for the protection of himself or the men under his direction shall follow the same procedure as the first workman and secure similar protection.

457. Reporting Clear—Transferring Responsibility

The workman in charge, upon completion of his work, and after assuring himself that all men under his direction are in safe positions, shall remove his protective grounds and shall report to the chief operator that all tags protecting him may be removed, and shall give his location and report as follows: "Mr. ——— and men clear and all grounds removed."

The workman in charge who received the permission to work may transfer this permission and the responsibility for men under him, as follows:

He shall personally inform the chief operator of the proposed transfer, and if this is permitted, the name of the successor shall be entered at that time on the tags concerned or in the records of the persons placing the tags and of the chief operator. Thereafter the successor shall report clear and shall be responsible for the safety of the original workmen, so far as this is affected by the removal of tags.

458. Removal of Tags

The chief operator shall then direct the removal of tags for that workman and the removal shall be reported back to him immediately by the persons removing them.

Upon the removal of any tag, there shall be added to the record the name of the chief operator and workman who requested the tag, the time of removal, and the signature of the person removing the tag.

459. Restoring Service

Only after all protecting tags have been removed by the above procedure from all points of disconnection shall the chief operator at his discretion, direct the removal of protective grounds and blocks and the closing of any or all switches and disconnectors.

Sec. 46. MAKING PROTECTIVE GROUNDS

When making temporary protective grounds on a normally live circuit the following precautionary measures shall be observed in the order given, and the ground shall be made to all wires of the circuit, which are to be considered as grounded.

460. Ground Connections

The employee making a protective ground on equipment or lines shall first connect one end of grounding device to an effective ground connection supplied for the purpose.

461. Test of Circuit

The normally live parts which are to be grounded should next be tested for any indication of voltage, the employee carefully keeping all portions of his body at the distance required from such parts when alive by the use of suitable insulating rods or handles of proper length, or other suitable devices.

462. Completing Grounds

If the test shows no voltage, or the local operating rules so direct, the free end of the grounding device shall next be brought into contact with the normally live part and securely clamped or otherwise secured thereto, before the employee comes within the distances from the normally live parts specified in rules 441 and 442, or proceeds to work upon the parts as upon a grounded part.

In stations, remote control switches can sometimes be employed to connect the equipment or lines being grounded to the actual ground connection. On lines it is generally necessary to resort to portable grounding devices or chains handled directly by means of insulating handles, rods, or ropes.

463. Removing Grounds

In removing a protective ground the employee shall not remove the grounding device from the ground connection until the device has been disconnected from all normally live current-carrying parts.

SPECIAL RULES FOR EMPLOYEES

Sec. 47. SUPPLY STATION AND SWITCHBOARD OPERATION

Engineers, machine attendants, switchboard operators and helpers shall study and strictly observe the following, in addition to all the general rules in sections 42 to 46, which apply to their work:

470. Care About Machines

Do not allow oil cans, tools, dusters, or wiping cloths to catch in moving parts of machinery. In passing any switchboard or machine in operation, do not touch it unnecessarily nor allow metal tools or other metal objects to touch the apparatus or connections. Do not use iron or tin oil cans near field magnets, and use only dusters and wipers with insulating handles on or about exposed live parts.

Any employee about to work on normally moving parts of electrical equipment during periods of rest shall protect himself against their accidental starting by placing "Men at work" signs on the starting devices, and locking or blocking these where practicable.

471. Care About Live or Moving Parts

Do not work on or near exposed live or moving parts unless authorized to do such work, and then strictly observe the rules applying.

When working near fuses and circuit breakers or other apparatus which may arc suddenly, be careful to avoid injury from their operation.

When working on one section of a switchboard or in one compartment, mark it conspicuously and place barriers to prevent your accidental contact with live parts in that section or adjacent sections.

When working on or about live parts and standing on insulated stools or ladders, or when otherwise insulated from the ground, avoid handing metal tools or other objects to other persons who are not insulated.

472. Handling Fuses or Brushes

In handling fuses above 750 volts, use the special rods or tongs and stand on insulating platforms or mats, where provided. Keep the body as distant and as far below as possible.

Replace or remove link fuses from live terminals and handle brushes on live equipment only when absolutely necessary, and then with due precautions.

473. Battery Rooms

Do not smoke or cause arcing in storage battery rooms. The use of open flames should be avoided, especially while the cells are gassing, and should be permitted only in special cases under the direct supervision of an experienced person, and after the room has been thoroughly ventilated.

Do not handle live parts of batteries or their connections, unless standing on insulating platforms or wearing suitable insulating boots.

474. Working in Elevated Positions

When working in an elevated position, especially above live or moving parts, assure yourself of the security of your position and support, and take precautions to avoid dropping tools or materials.

475. Handling Switchboard Equipment

All ungrounded metal parts of devices on switchboards shall be handled as if operating at the highest voltage to which any portion of the equipment on the same switchboard panel is subject, unless the parts are known, by test or otherwise, to be free from such voltage.

When cable plug connectors are used, do not allow one end to remain hanging loose while the other end is connected to a live terminal.

In handling instrument circuits, the secondary of a current transformer should never be opened when it is alive.

476. Reporting Circuit Trouble to Chief Operator

Report to your immediate superior or to the chief operator any unusual conditions of load, and the indication of any accidental ground on an outgoing circuit.

477. Reporting Defects

Promptly report to your superior any dangerous conditions of equipment or surroundings, including defective tools, switches, or protective devices, or live cases or frames of apparatus or instruments.

Sec. 48. OVERHEAD LINE OPERATION

Linemen and assistants and groundmen, in construction, extension, removal, or repair work, shall study and strictly observe the following, as well as all the general rules in sections 42 to 46, which apply to their work.

480. Testing Structures Before Climbing

Before climbing poles, ladders, scaffolds, or other elevated structures, first assure yourself that the pole, ladder, scaffold, tree, crossarm, messenger wire, cable car, or boatswain's chair, or other elevated support, is strong enough to safely sustain your weight.

Poles may be tested for decay near the ground line with a bar, screw driver, or other tool, and sounded for decay at the center by rapping with a heavy tool or block of wood.

When poles or crossarms are apparently unsafe from decay or unequal strains of wires on them they should be properly braced or guyed, if necessary, before they are climbed.

481. Use of Pole Steps

When poles are stepped, make use of such steps in climbing.

Do not support yourself by pins, brackets, or conductors.

482. Spurs

Spurs with gaffs worn short shall not be used. The gaff on spurs shall be kept sharp, and spurs shall fit properly. Spurs shall not be worn on work for which they are not required, nor while men are traveling to or from work.

483. Care About Live Parts

Do not go among any wires until you know their voltage.

Leaning over and crowding through unprotected wires should be avoided wherever possible. Place yourself so that you will not be liable to fall on wires should an accident occur.

Do not depend on the insulating covering of wires, and treat all lines as alive unless they have been properly killed (except signal lines known to be clear).

Avoid use of hand lines or measuring tapes containing metal strands.

In handling dangerous switches or fuses do so only by means of suitable insulating handles, rods, or tongs.

484. When Touching Live Parts

When working on live equipment or lines never allow any portion of the body to come in contact with any live or grounded part other than that worked on.

While touching supply lines or equipment, avoid as far as possible touching ground wires, guy wires, span wires, metal pipes, metal poles, metal sheaths, signal lines or equipment, transformer cases, hangers, and other metal fixtures.

Signal lines are included principally because of their liability of being grounded.

The other equipment and lines listed may become either alive or grounded.

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While touching signal lines or equipment, metal sheaths, metal pipes, ground wires, or metal fixtures on poles, avoid as far as possible touching supply lines or equipment, guy or span wires.

485. Protecting Traffic

When working overhead, keep tools and materials not in use in proper receptacles; tools or materials should not be thrown to or from the man on the pole, but should be raised or lowered by means of a hand line, using proper receptacles where practicable.

Do not unnecessarily stand where you can be struck by materials dropped by men working overhead.

Pole holes and obstructions along public highways and other frequented places shall be protected by watchmen or by suitable guards or danger signals so located as to be conspicuous to traffic.

When working overhead, or hoisting or lowering materials above places where frequent traffic occurs, a man should be stationed to warn passers-by.

Where traffic is light, warning signs or barriers may be used in lieu of watchmen. Where traffic is congested, it may be necessary to rope off the space.

486. Stringing Lines

Never string wire near live lines except by means of suitable insulating hand lines or other appliances. Avoid bringing them in contact with the live lines. Regard them as live wires of the same voltage because of their liability to come in contact with the live lines.

Never change the strains on a pole by adding or removing wires until assured that the pole will stand the altered strains.

In stringing wires do not allow them to sag so as to endanger vehicles or pedestrians below, unless traffic is intercepted by watchman or otherwise.

487. Reporting Defects

Report promptly to your immediate superior any dangerous conditions of your own or other utilities observed arising from defective insulators, pins, crossarms, abnormally sagging wires, etc.

Sec. 49. UNDERGROUND LINE OPERATION

All cable splicers and other workmen in underground construction or operation shall study and strictly observe the following in addition to the general rules in sections 42 to 46, which apply to their work.

490. Guarding Manholes, Handholes, and Street Openings

When removing manhole or handhole covers or making excavations, promptly protect the opening with a barrier, temporary cover, or other suitable guard, and see that danger signals or red lights are displayed in a location conspicuous to the traffic until permanent covers are in place or the excavations are filled.

491. Testing for Gas

Do not enter manholes until you have assured yourself that the manholes are free from dangerous gases, by testing with approved safety lamps, by ventilation, or by other adequate methods. (See rule 581.)

492. Watchman on Surface at Manholes

Do not enter a manhole unless a temporary cover is placed over the opening or a watchman is stationed at the surface. Where any gas is liable to be present always see that the watchman is stationed at the surface. Where any hazard is involved do not leave a manhole unwatched until all workmen are out.

493. Avoiding Flames

Do not smoke in manholes and avoid as far as practicable open flames or torches in or near manholes.

Avoid sparks in handling live parts or cable sheaths and avoid igniting the flux in soldering and wiping joints. In using hot paraffin see that it does not reach a temperature at which it will ignite. (See rule 583.)

494. Pulling Cables

When pulling in cables make sure that the gear can not slip so as to injure workmen. Avoid the danger of having the hands drawn into the tackle by the pulling line.

495. Testing and Splicing Live Cables

If lines and cables are not properly identified by markings or positions, do not work upon them.

Always ascertain, if practicable, whether cables are alive, by testing with the test devices provided, before cutting into the cable sheaths. Live cable should be spliced only by men experienced in the work, and they should use extreme caution and suitable devices in so doing.

496. Reporting Defects

Promptly report to your immediate superior any dangerous condition of your own or other utilities, whether observed in underground or overhead construction. Particularly report insanitary conditions, gas or missing cable tags in manholes, and abnormally sagging wires or broken supports in overhead construction.

Sec. 50. SERIES LAMP OPERATION

All series lamp trimmers, hangers, and inspectors shall study and strictly observe the following, in addition to the general rules in sections 42 to 46, and the special rules under the sections for overhead and underground operation, respectively, in sections 48 and 49, which apply to their work.

500. Precautions on Series Circuits

Series lamps and devices in series circuits should always be treated as alive unless disconnected by absolute cut-outs or protected by the grounding of the circuit (see section 46).

501. Handling Series Lamps

Trimmers, inspectors, or patrolmen shall wear suitable insulating gloves and stand on insulating platforms or dry, well-seasoned wood poles while touching series lamps or their cut-outs, when these are alive.

Where stools or tower wagons are used which provide sufficient insulation from ground for the voltages to be handled, the insulating gloves may be dispensed with.

502. Bridging Series Lamps

Before working on lamps or other devices in live series circuits always bridge the device with jumpers such as series lamp cut-outs usually provide, so that the circuit can not be opened at the device and possibly be completed through your body or arc at the point of opening and burn you.

503. Testing Series Lamp Circuits

Series lamp circuits should not be tested at their full operating voltage unless it is impracticable to test otherwise. Tests should be made only in accordance with a time schedule, concerning which all persons whose safety may be affected are informed.

504. Periodically Disconnected Circuits

If circuits, such as series lamp circuits, are not effectively grounded during the idle period, all rules for handling live parts shall be strictly observed.

505. Reporting Defects

Report promptly to your immediate superior any abnormally sagging wires, broken insulators, leaning poles, defective pole steps, broken globes or lamp supports, and other defects giving rise to a dangerous condition of your own or other utilities, or any indication of voltage on lines supposed to be dead.

Sec. 51. METER OPERATION

All meter setters and testers shall study and strictly observe the following in addition to all the general rules in sections 42 to 46, which apply to their work.

510. Taped Joints

Never leave joints or loose ends of wires untaped unless otherwise protected.

511. Care About Live Parts

Do not use bare fingers or hands to determine whether a circuit is alive. Never remove or replace fuses in live circuits above 750 volts except by means of the suitable appliances provided.

512. Opening Circuits At Switches

Special care should be exercised in opening circuits at meter connections unless the circuits have been first properly opened at switches.

513. Current Transformer Secondaries

Before working on an instrument or other device in a current transformer secondary circuit always bridge the device with jumpers, so that the circuit can not be opened at the device. Never open such a circuit at meter connections until it has been elsewhere bridged.

514. Special Tools

Use only hand tools suited to the work in hand, and so reduce the danger of short circuits.

515. Reporting Defects

Promptly report to your immediate superior any live meter case or any condition of a meter or its connections of the interior wiring or of overhead lines, of your own or other utilities, which might endanger life and property.

Sec. 52. TESTING OPERATIONS

All electrical testers, helpers, and others working about electrical tests shall study and strictly observe the following in addition to all the general rules in sections 42 to 46. Owing to the diversified character of testing work this study should usually extend also to the special rules in sections 47 to 54.

520. Authorization for Work

Do not work on or about equipment or lines without first receiving authorization from the person in charge.

If such equipment or lines are under control of a chief operator, this authorization must come from him. This will include the attaching of tags at the proper points and the observation of all rules for general operation in section 43.

521. Checking of Conditions

Thoroughly familiarize yourself with all conditions surrounding equipment or lines to be tested before making any change in these conditions.

Do not make any change in equipment or lines unless you fully understand the effect of the change.

522. Foreman

One properly qualified person shall be in immediate charge of all testing work, or all of the workmen shall be instructed as to the work they are to perform and the employee instructing them shall be considered in charge of the work.

523. Warnings and Barriers

Display danger signs and erect suitable guards about all equipment or lines under test when in places where traffic is frequent, if live or moving parts would otherwise be exposed.

When temporary wiring, belts, pulleys, or other temporary live or moving parts must be guarded, suitable portable guards and warning signs shall be used.

524. Requirement for Two Workmen

No person should work alone in testing or experimental work on or about parts on which the voltage can exceed 750 volts, except in routine testing where the live parts are properly guarded.

525. Reporting Defects

Promptly report to your immediate superior any conditions of equipment or lines under test which may endanger life or property.

Sec. 53. TUNNEL AND SUBWAY OPERATION

Tunnel and subway electricians, operators, and others working on or about underground electrical equipment (not in stations, substations, or in underground conduit systems) shall study and strictly observe the following, in addition to the rules in sections 42, 43, 44, 47, and 49, so far as they apply to their work.

Dangerous Locations.—The value of insulation (insulating covering) as protection from shock is reduced by the dampness usually present in these and similar locations. The restricted spaces often bring the worker closer to equipment and wires than in other kinds of electrical work, and the imperfect illumination also makes special care necessary to avoid contacts. The human body and all surrounding surfaces become more conducting where dampness exists, and electrical shocks are therefore more severe.

530. Live Electrical Parts

Before handling any electrical equipment or wires, make sure whether they are alive or dead. It is not advisable to work on live equipment or wires when the current can be shut off without interrupting necessary operations.

Never touch or disturb any electrical equipment or wires without being authorized.

531. Standing on Ground

Do not touch any electric wire, cable, or third rail, no matter how well it is insulated, while you are standing on the ground or on any pipe, track, rail, or other conducting surface, unless insulated from the latter.

Do not touch the metal frame or case of a motor unless you are insulated from the ground or the frame is effectively grounded.

Remember that the surfaces of damp ground and water are conducting.

Insulation on a wire may look perfect, but it can not be relied on to prevent shock.

532. Carrying Tools

In carrying tools or metal implements in passageways containing electric wires, especially near exposed trolleys, never permit the tools or implements to touch them.

In particular, do not carry such objects on the shoulder when there are conductors overhead. Do not carry objects on that side of passageways where third rails or side trolley wires are exposed.

533. Handling and Repairing Live Parts

When necessary to handle or repair live trolley wires, third rails, cables, motors, or other electrical equipment, wear suitable insulating gloves or stand on the waterproof insulating mats or platforms provided.

Do not rely entirely on gloves for protection. The gloves may have been punctured since they were previously tested.

Before handling or making use of any electrical cable, carefully examine it to make sure that its insulation is not injured.

Portable cables should be inspected at least once daily during the period of their use.

534. Handling Portable Devices

In handling portable motors or lamps, first make sure that the external metal frame is not alive by contact with or leakage from live parts within.

Have such portable devices inspected at least once daily during the period of their use.

535. Fuses and Switches

Never handle fuses or close switches or circuit breakers unless you are authorized to perform that special duty, and then use the insulating handles or rods provided.

Before closing switches first make sure that you are not endangering other persons.

536. Injuring Cables and Wires

Do not fire shots, handle tools, or perform other work in such a manner as to injure cables or wires in the vicinity. If in doubt, consult your superior.

537. Temporary Wiring

Never arrange the wiring of any temporary circuit for earth return, nor use bare conductors.

This particularly applies to the temporary portions of shot-firing circuits and to the leads of portable motors and lamps.

Never employ temporary circuits without seeing that there are installed at the junction with the permanent wiring, suitable disconnecting switches or plug connectors, arranged to disconnect all conductors of the temporary circuit by a single operation.

For shot-firing circuits their disconnectors should be left open until the shot is to be fired, and should preferably be arranged for locking in the open position.

538. General Precautions

Never get on or off locomotives or cars on the side where the trolley wire or third rail is located.

Do not place combustible or explosive materials near electric wires, trolley tracks, third rails, or motors.

Do nothing that will cause sparking, or expose parts that may arc or spark during operation, if any explosive gases are present.

539. Reporting Dangerous Conditions

Promptly report to your superior any dangerous or unusual conditions observed. In particular, report the presence of gas, broken insulators, bad insulation on wires, defective third-rail construction, live frames of motors, broken ground wires on motor frames, and sparking, arcing, or shocks noticed at any point.

Report also any fallen, crossed, or abnormally sagging wires, whether electric wires or not. This includes trolley wires at switches and crossings and wires injured through falling roofs.

Sec. 54. SIGNAL LINE OPERATION

All men working on or near telephone and telegraph lines operated in connection with supply lines shall study and strictly observe the following, in addition to all the general rules in sections 42, 43, and 44, and the special rules in sections 48 and 49, which apply to their work. For rules governing the operation of commercial signal lines see sections 55–58.

540. Official in Charge of Operations

In those rules where the words "chief operator" are used the official in charge of safeguarding operation is to be understood.

541. Precautions Before Climbing Poles

Before climbing poles or other structures to work on or about signal lines, especially where occupied in common with, or running near power circuits, make a careful inspection to ascertain if possible whether there are any crosses with supply circuits.

Apply mechanical tests as far as practicable to messenger wires before trusting the wires to carry your weight.

542. Approaching Supply Lines

Avoid contact with all wires other than those you know to be signal wires, assuming such other wires always to be alive. Signal wires in trouble may be in contact with supply lines at some distant point and should be treated with proper care.

Do not approach any supply line or supply equipment within the distances given in rules 441 and 442 unless you comply with all the rules under that section, as far as they apply.

543. Touching Equipment

While handling signal lines, metal sheaths, or signal equipment avoid touching guy or span wires and supply lines or equipment. Especially avoid standing on or touching transformer cases, hangers, or connections.

While touching open signal lines avoid contact also with grounded parts such as sheaths and ground wires.

544. Stringing Wires

When stringing wires or cables over or under supply lines, avoid any possibility of their coming in contact. Do not string them above live supply lines where it is practicable to avoid it.

Where liability of contact can not be entirely avoided, the lines being handled shall be treated as alive (unless they are effectively grounded), and the rules in section 44, so far as they are applicable, shall be carefully observed.

545. Reporting Dangerous Conditions

Promptly report to the proper official abnormally sagging wires, broken or defective insulators, pins, crossarms, defective poles, or any other dangerous conditions of your own or other utilities.

RULES FOR COMMERCIAL TELEPHONE AND TELEGRAPH SYSTEMS

These rules apply also to fire and police alarm systems, district messenger systems, and other signal systems not operated in connection with supply lines. For rules on the latter see section 54.

Sec. 55. RULES FOR THE EMPLOYER—SIGNAL SYSTEMS

550. Distribution and Enforcement of Rules

(*a*) The employer shall furnish to each regular employee working on or about commercial telephone or telegraph equipment or lines safety rules governing his conduct while so engaged, and shall take suitable means to secure the employee's compliance with the same.

(*b*) The safety rules furnished to any employee may be in such form as the employer may determine is best suited to the needs of individual employees. They shall, however, include the principles set forth in the following rules, or at least such part thereof as is applicable to the work in which the employee is engaged, and shall not conflict with these rules.

(*c*) If a difference of opinion arises with regard to the meaning or application of these rules, or as to the means necessary to carry them out, the decision of the employer or his authorized agent shall be final, subject to an appeal (if taken) to the regulative body having jurisdiction.

551. Address List and Emergency Rules

The rule books should contain or be accompanied by the following:

(1) A list of names and addresses of those physicians and members of the organization who are to be called upon in emergencies.

(2) A copy of rules for first aid, resuscitation, and fire extinguishment.

These should also be kept in conspicuous locations in central stations, on line wagons, and in other locations where the number of employees and nature of the work warrants.

552. Instructing Employees

Employees regularly working on or about signal equipment or lines, if their duties render such training necessary, shall be thoroughly instructed in approved methods of first aid, resuscitation, and fire extinguishment, and if advisable regularly drilled.

Groups of employees, such as commercial telephone operators, shall be thoroughly drilled to make prompt and orderly exit from buildings in case of fire.

553. Qualification of Employees

The employer shall use every reasonable means and precaution to assure himself that each employee is mentally and physically qualified to perform his work in accordance with these rules, and that he is not addicted to the use of intoxicants and habit-forming drugs.

554. Protective Devices

There shall be provided in conspicuous and suitable places in stations and on line wagons a sufficient supply of suitable protective, first-aid, and fire extinguishing equipment to enable employees to meet the requirements of these rules. Such devices and equipment shall be inspected or tested to insure that they are kept in good order. The following is a list of suitable devices and equipment, the kinds and numbers of which will depend on the requirements of each case: (*a*) First-aid outfits; (*b*) insulating wearing apparel, such as insulating gloves, boots, and shields; (*c*) safety belts; (*d*) fire-extinguishing apparatus.

Sec. 56. GENERAL RULES FOR THE EMPLOYEE—SIGNAL SYSTEMS

560. Heeding Warnings, Warning Others

Employees should cultivate the habit of being cautious, heed warning signs and signals, and always warn others when seen in danger near equipment and lines.

561. Inexperienced or Unfit Employees

No employee shall do work for which he is not properly qualified on or about equipment or lines, except under the direct supervision of an experienced and properly qualified person.

562. Electrical Supply Equipment or Lines

Workmen whose duties do not require them to approach or handle electrical supply equipment and lines should keep away from such equipment or lines.

Electrical supply equipment and lines should always be considered as alive unless positively known to be dead.

563. Safe Supports and Safety Belts

(*a*) Safe Supports.—Employees should not support themselves on any portion of a tree, pole structure, lamp bracket, or similar fixtures on poles, scaffold, ladder, roof, skylight, or other elevated structure without first making sure that the supports are strong enough, reinforcing them if necessary.

Portable ladders should be in a safe position before being climbed. The slipping of a ladder at either end should be carefully guarded against, especially where the surfaces are smooth or vibrating.

Insecure makeshift substitutes for ladders should not be used. An employee should never trust his weight on thin wooden boxes, sinks, washbowls, window shelves, or chair backs.

A ladder should not be placed upon a box, barrel, or other movable or insecure object.

Care shall be taken to see that chairs, rolling ladders, and similar equipment are in first-class condition before being used.

(*b*) Safety Belts.—Employees should not work in elevated positions unless secured from falling by a suitable safety belt or other adequate means (sometimes including suitably located pole steps). Before an employee trusts his weight to the belt, he should determine that the snaps or fastenings are properly engaged and that he is secured in his belt.

(*c*) Safety Ropes.—Ropes used for supporting boatswains' chairs, platforms, or for other purposes on which the security of the employee depends shall be frequently inspected to assure that they are maintained in good condition.

564. Duties of Foreman

(*a*) Each foreman in charge of work (see rule 406) shall see that the safety rules are observed by the employees under his direction. He shall make all necessary records; reporting to his superior when required. He shall permit only authorized persons to approach places where work is being done.

He shall adopt such precautions as are within his power to prevent accidents, and prohibit the use of any tools or devices not suited to the work in hand or defective.

(*b*) The qualified person accompanying uninstructed workmen or visitors near electrical equipment or lines shall take precautions to provide suitable safeguards and see that the safety rules are observed.

565. Handling Live Parts

No employee should touch, with bare hands, any exposed ungrounded live part above 150 volts to ground, unless he is insulated from other conducting surfaces, including the ground itself. When employees must touch, at the same time, two parts between which a considerable potential exists, insulating gloves or other protection shall be used.

566. Power Circuits in Central Offices

When making repairs on electric light or power circuits, the circuits shall, whenever possible, be made dead.

Where practicable, moving apparatus, as for example, fans, shall be stopped before working upon it.

None other than duly authorized persons shall be admitted to central office transformer vaults or battery rooms.

Care shall be used while working on or near circuits over 150 volts to ground, particularly in alternating-current districts.

567. Handling Fuses or Brushes

When working on the brushes of a machine in operation, employees shall use care not to break a circuit, the flashing of which may injure the eyes or burn the hands. If it is necessary to remove a brush from the holder, the machine shall be shut down.

When inspecting or changing fuses, care should be taken to prevent injury to the eyes. If it is necessary to handle the fuses, the circuit should be cut off, if possible.

568. Battery Room

Do not smoke or cause arcing in storage-battery rooms. The use of open flames should be avoided, especially while the cells are gassing, and should be permitted only in special cases under the direct supervision of an experienced person and after the room has been thoroughly ventilated.

Sec. 57. SPECIAL RULES FOR OVERHEAD LINE OPERATION—SIGNAL SYSTEMS

570. Testing Structures Before Climbing

Before climbing poles, ladders, scaffolds, or other elevated structures first assure yourself that the pole, ladder, scaffold, tree, crossarm, messenger wire, cable car, or boatswain's chair, or other elevated support is strong enough to safely sustain your weight.

On pole replacement work no pole shall be climbed for the purpose of clearing it of all wires and cables without first guying or bracing the pole securely.

Where poles or crossarms are apparently unsafe from decay, or unequal strains of wires on them, they should be properly braced or guyed, if necessary, before they are climbed.

An uncoiled hand line, rope, or wire of any sort should not be fastened to the employee while climbing a pole, but where this must be done the employee should exercise due care to prevent the line from catching on obstructions.

In climbing poles careful watch should be kept for nails or other foreign attachments which might catch in the clothing and cause a fall.

571. Use of Pole Steps

When poles are stepped, make use of such steps in climbing, first making sure that the steps are firmly set in solid material before trusting one's weight upon them. Pay particular attention, on icy poles, to each step.

Do not support yourself by pins, brackets, or conductor wires.

572. Spurs

Spurs with gaffs worn short shall not be used. The gaff on spurs shall be kept sharp, and spurs shall fit properly. Spurs shall not be worn on work for which they are not required, nor while men are traveling to or from work.

573. Approaching Supply Lines

Avoid contact with all wires other than those you know to be signal wires, assuming such other wires always to be alive. Signal wires in trouble may be in contact with supply lines at some distant point, and should be treated as live supply lines unless known to be free from any dangerous voltage.

Do not approach any supply line or supply equipment within the distances given in rules 441 and 442 under section 44, unless you comply with all the rules under that section.

574. Touching Equipment

While handling signal lines, metal sheaths, or signal equipment, avoid touching trolley or arc lamp span wires and supply lines or equipment. Especially avoid standing on or touching transformer cases, hangers, or connections.

575. Care About Electrical Supply Lines

Do not go among any wires until you know their voltage.

Leaning over and crowding through unprotected supply wires should be avoided wherever possible. Place yourself so that you will not be liable to fall on supply wires should an accident occur.

Do not depend on the insulating covering of wires, and treat all lines as alive unless they have been killed properly (except signal lines known to be clear).

Treat also as alive all wires (unless thoroughly grounded) which are being strung near supply lines; regard them as being of the same voltage as the supply lines.

Avoid use of hand lines or measuring tapes containing metal strands.

When necessary to work in the vicinity of supply lines, transformers, and similar equipment, assure yourself before starting work that the position of the body is such that should you momentarily forget yourself or fall no portion of the body will come in contact with the foreign wires or equipment. Have the supply lines approached killed where possible.

Railway span wires, pull offs, and trolley brackets shall be treated as if alive, even though equipped with strain or other insulators.

576. Stringing Lines

Never string wires near live lines except by means of suitable insulating hand lines or other appliances.

Avoid the use of wire or twisted pair as a substitute for a hand line.

Wires should not be strung above live lines operating at over 750 volts, unless the wires being strung are effectively grounded or otherwise suitably protected, or in handling them all the precautions are observed as provided in rules 441 and 442, for work on parts at the voltage of the lines concerned, and the spacings maintained.

Never change the strains on a pole by adding or removing wires until assured that the pole will stand the altered strains.

When wires are being pulled up on corner poles employees should stand in such a position that they can not be struck by the wire in case it slips.

Where it is necessary to remove signal wires below which are supply lines, power should be shut off of the supply lines where possible, and if this is not practicable, rope cradles and suitable guards should be erected. Extraordinary care should be exercised to prevent the signal wires from sagging into the supply lines.

When running wires, cables, cable strand, span wires, or guys across streets, sidewalks, or highways, the coil or reel shall not be left unattended, nor shall the center of any span be permitted to sag sufficiently to come into contact with vehicles or pedestrians unless a helper is stationed to warn passers-by until the slack can be removed.

When stringing wires for long distances, precautions shall be taken to prevent the possibility of vehicles or pedestrians coming into contact with the wires at the intersecting streets or highway crossings.

577. Protecting Traffic

When working overhead, keep tools and materials not in use in proper receptacles; tools or materials should not be thrown to or from the man on the pole, but should be raised or lowered by means of a hand-line, using a proper receptacle. Also tools and loose materials should not be left at the top of poles, ladders, or other elevated structures.

Workmen shall not stand where they are liable to be struck by materials dropped by men working overhead.

Pole holes and obstructions shall be protected by watchmen or by suitable guards and danger signals or lights in a location conspicuous to traffic.

When working overhead or hoisting or lowering materials above places where traffic occurs, a man should be stationed to warn passers-by.

Where traffic is light, warning signs may be used in lieu of watchmen. Where traffic is congested, it may be necessary to rope off the space.

578. Reporting Dangerous Conditions

Report promptly to your immediate superior any dangerous conditions of your own or other utilities observed arising from defective insulators, pins, crossarms, abnormally sagging wires, etc.

Any imminently dangerous conditions shall be guarded until they can be made safe.

Sec. 58. SPECIAL RULES FOR UNDERGROUND LINE OPERATION—SIGNAL SYSTEMS

580. Guarding Manholes, Handholes, and Street Openings

When removing manhole or handhole covers or making excavations, promptly protect the opening with a barrier, temporary cover, or other suitable guard, and see that danger signals or red lights are displayed in a location conspicuous to the traffic until permanent covers are in place or the excavations are filled.

581. Testing for Gas

Do not enter manholes until you have assured yourself that the manholes are free from dangerous gases, as indicated by approved safety lamps, by ventilation, or by other adequate methods.

When work is being carried on in manholes for any length of time where gas collects, suitable ventilation shall be provided or tests with the safety device should be repeated at regular intervals to make certain that gas is not accumulating in the manhole in dangerous quantities.

582. Watchman on Surface at Manhole

Do not enter a manhole unless a man is stationed at the surface. Do not leave a manhole unwatched until all workmen are out.

583. Avoiding Flames

Do not smoke in manholes, and avoid as far as practicable open flames or torches in or near manholes.

If it is necessary to illuminate a manhole, electric lights only should be used. When doing this, it should be known that the leads, sockets, and connections are well insulated and in good condition in order to avoid the possibility of a spark. Special attention should be paid to the sparking of any motors used for ventilating purposes.

Avoid sparks in handling live parts or cable sheaths, and avoid igniting the flux in soldering and wiping joints. In using hot paraffin see that it does not reach a temperature at which it will ignite.

In central office cable vaults tests shall be made for the presence of gas before using exposed flames, and such flames shall not be used in vaults where gas collects.

584. Pulling Cables

When pulling in cables, make sure that the gear can not slip so as to injure workmen. Avoid the danger of having the hands drawn into the tackle by the pulling line.

585. Reporting Dangerous Conditions

Promptly report to your immediate superior any dangerous condition of your own or other utilities, whether observed in underground or overhead construction. Particularly report insanitary conditions, gas, or missing cable tags in manholes and abnormally sagging wires or broken supports in overhead construction

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DISCUSSION OF PART IV—OPERATION OF ELECTRICAL EQUIPMENT AND LINES

SCOPE

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 manu facturing 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 "fool proof." 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. 40. ORGANIZATION

400. Interpretation and Enforcement of Rules

(*a*) 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.

(*b*) 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.

401. Organization Diagram

The organization diagram is important in small as well as large organizations, so that team work 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.

402. Address List and Emergency Rules

In emergencies, memory can not always be depended upon. Even the best trained man may lose his 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.

403. Instructing Employees

The instruction of employees in methods, for the resuscitation of persons rendered unconscious electrically, 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 practicable the enthusiasm and team work 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.

404. 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. As it is so difficult to test the exact effect of the use of intoxicants on some individuals, and as the danger is in general so apparent, many companies have found it advisable to prohibit all use of intoxicants at any time. Others have limited this restriction to working hours. There is a growing tendency toward greater strictness in this regard.

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.

405. 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 in 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 have other duties occupying most of his time, but from which he can detach himself when necessary to direct operation.

406. 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.

Sec. 41. PROTECTIVE METHODS AND DEVICES

410. Attendance

Some tendency exists in certain cases to encourage the use of stations not under regular attendance during operation. 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.

The National Electrical Code, under rule 6, has for years required an attendant to be present where generators are operated. It has not seemed feasible to make such a requirement in the National Electrical Safety Code, although it is generally desirable in order to make the service supplied safer and more reliable, and the rule referred to has the approval of the National Electric Light Association.

411. 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.

412. Uninstructed 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.

413. 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.

414. 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.

415. 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.

416. Warning and Danger 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.

Even where authorized persons only 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.

Sec. 42. GENERAL PRECAUTIONS

420. 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.

421. 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.

422. 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.

423. 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.

425. Live and Arcing Parts

(*a*) 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.

(*b*) 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.

426. Safety Appliances and Suitable Clothing

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. 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.

427. Safe Supports and Safety Belts

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. 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.

429. Repeating Messages

Many accidents are due to misinterpretation of instructions or information, and the practice of 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 later preserved for reference and to assist the memory on details. This is of particular value for long messages.

Sec. 43. GENERAL OPERATION

430. 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.

431. 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.

432. Special Authorizations

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 under 7500 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.

433. Restoring Service After Work

One of the most serious possibilities for hazard in connection with work on supply lines is that, being carried on in 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.

434. Maintaining Service

(*a*) 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.

(*b*) 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.

(*c*) 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 patroling is always desirable.

435. 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.

436. 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.

437. Protecting Workmen by 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 above 750 volts, unless the oil is very clean and free from moisture. The grounding of a circuit as required by section 45, 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.

Sec. 44. HANDLING LIVE EQUIPMENT AND LINES

440. General Requirements

(*a*) 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.

(*b*) 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.

(*c*) 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.

(*d*) CUTTING INTO INSULATING COVERINGS 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 section 45. 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.

441. Voltages Between 750 and 7500

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 conditions, 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 sleeve, 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.

442. Voltages Above 7500

Work on or about live lines or equipment over 7500 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 40 000 volts or over can be tied to insulators, and other similar work accomplished with apparently no greater hazard than accompanies the handling of ordinary 2300-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 169.)

It is the general experience that the forming of safe habits soon results in involuntary carefulness and will minimize loss of time.

443. Requirement for Two Workmen

See discussion on rule 411.

444. When to Kill Parts

When it is for any reason impracticable to use the precautions given in rules 440, 441, and 442, 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 section 45 should be carefully followed. In this way dangerous mistakes and misunderstandings will be avoided.

445. Operating Switches and Working From Below

(*a*) 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.

(*b*) 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.

446. 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.

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.

447. 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 light, 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.

Sec. 45. KILLING SUPPLY EQUIPMENT AND 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 the introduction to section 45.

Sec. 46. MAKING PROTECTIVE GROUNDS

The requirement that an effective ground connection be made before contact is made between the grounding device and the lines, 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.

461. Test of Circuit

Many devices have been suggested, and are in use to a limited extent, for testing circuits to show the presence of voltage, without mechanically touching the circuits. All so far proposed have the disadvantage that they can not be generally applied to all kinds of circuits. For instance, the electroscope is used in some cases. Hammers and other metal tools mounted on sufficiently insulated handles are used to indicate voltage by drawing off a discharge when presented to a high-voltage line. Sometimes a telephone receiver is used in conjunction with an exploring coil to produce an audible signal when the coil is near an energized cable.

Much is expected in the way of detecting the presence of alternating current voltages in a visible manner by use of the neon tube and other tubes, containing rarified gases, with electrodes for introducing a charge.

463. 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. 47. SUPPLY STATION AND SWITCHBOARD OPERATION

470. 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 section 45, 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.

471. 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.

Sec. 47 TO 54, INCLUSIVE

These sections are 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. If additional discussion seems desirable, it may be best to place it in the form of descriptions of accidents which are recorded as having been caused by lack of observance of certain of the required precautions.

Sec. 48. OVERHEAD LINE OPERATION

480. Testing Structures Before Climbing

See discussion on rule 570.

481. Use of Pole Steps

See rule 571.

486. Stringing Lines

See rule 576 and discussion.

Sec. 49. UNDERGROUND LINE OPERATION

491. Testing for Gas

See discussion on rule 581.

493. Avoiding Flames

See discussion on rule 583.

Sec. 55. RULES FOR THE EMPLOYER—SIGNAL SYSTEMS

550. Distribution and Enforcement of Rules

See discussion on rule 400.

551. 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 be as far as practicable avoided. See discussion on rule 402.

552. Instructing Employees

See discussion on rule 403.

553. Qualification of Employees

Any person addicted to the use of intoxicants to excess when off duty should not be considered a desirable employee. The use of intoxicants when on duty may be considered sufficient cause for dismissal. See discussion on rule 404.

554. Protective Devices

See discussion on rule 415.

Sec. 56. GENERAL RULES FOR THE EMPLOYEE—SIGNAL SYSTEMS

560. Heeding Warnings, Warning Others

See discussion on rule 421.

561. Inexperienced or Unfit Employees

See discussion on rule 422.

562. Electrical Supply Equipment or Lines

See discussion on rules 421 and 425.

563. Safe Supports and Safety Belts

(*a*) 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.

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.

(*b*) When an employee finds a belt to be defective, he should immediately exchange it for a serviceable one.

564. Duties of Foreman

See discussion on rule 431.

565. Handling Live Parts

See discussion on rule 440 *a* and *b*.

568. 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 explosions.

Sec. 57. SPECIAL RULES FOR OVERHEAD LINE OPERATION—SIGNAL SYSTEMS

570. Testing Structures Before Climbing

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.

576. Stringing Lines

Signal wires being strung near supply lines should not be touched with the bare hands. Suitable rubber gloves should always be worn.

In pulling the signal wires over electric light, power, or other foreign wires, the hand line should at all times be kept sufficiently taut to prevent the signal 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 stress 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 stress 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 stress is removed from one side only, temporary guying on one side may be sufficient.

Sec. 58. SPECIAL RULES FOR UNDERGROUND LINE OPERATIONS—SIGNAL SYSTEMS

581. 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 the manhole opening.

583. 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 paraffine, care shall be used to avoid splashing or spilling.

DEPARTMENT OF COMMERCE

BUREAU OF STANDARDS

S. W. STRATTON, Director

INDEX TO PARTS 1, 2, AND 3 OF CIRCULAR NO. 54, "THE NATIONAL ELECTRICAL SAFETY CODE, SECOND EDITION"

Rules 100 to 185, inclusive, are for stations.

Rules 200 to 299, inclusive, are for lines, including complete segregated specifications for crossings, conflicts and common use of poles.

Rules 300 to 393, inclusive, are for utilization.

Rules 400 to 585, inclusive, in part 4, are not indexed because of the general brevity of these rules and the simplicity of their arrangement, and because of the fact that rules pertaining to any one subject are grouped together and should be considered collectively. Thus an index would simply resolve itself into an alphabetical list of section titles, which are now readily referred to in the table of contents, pages 267 to 270, inclusive.

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