DEPARTMENT OF COMMERCE

# CIRCULAR

OF THE

# BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 54

# PROPOSED NATIONAL ELECTRICAL SAFETY CODE

PRELIMINARY EDITION
SUBMITTED FOR DISCUSSION AND CRITICISM
NOT FOR ADOPTION

ISSUED APRIL 29, 1915

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

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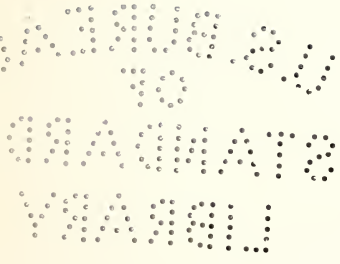

# PROPOSED NATIONAL ELECTRICAL SAFETY CODE

CONTENTS



## INTRODUCTION

The Bureau of Standards has been engaged for more than a year in the preparation of a National Electrical Safety Code. This preliminary publication contains three of the four principal parts of the code, the fourth part containing operating rules having been taken up first and published in preliminary edition about eight months ago. The three parts now published for discussion and criticism will be thoroughly revised after further study, and after consideration and approval by a conference called for the purpose will be republished with the operating rules as a complete code.

There is also included in this circular a set of notes on the rules which are intended to make clearer the meaning and application of the rules. These notes will be revised and extended in the next edition, with the hope that they may be useful to companies in complying with the rules and to commissions and municipalities in administering the code.

The Bureau has had the cordial cooperation of some of the 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 the work has been rapid, considering the magnitude of the task; and it is hoped that when completed it will receive the very general support of the interests affected by it.

This electrical safety code 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. More than a year ago the Bureau offered to cooperate with the electrical committee in framing safety rules to be incorporated in the present electrical code. But at a conference last November with representatives of the electrical committee and the safety to life committee of the N. F. P. A. it appeared 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 simplified their preparation, and to some extent also their administration, although there may be some difference of opinion among inspectors as to the latter.

An understanding was reached between the representatives of the Bureau of Standards and the two committees representing the N. F. P. A. that the Bureau of Standards should take the responsibility of preparing a National Electrical Safety Code, with the cooperation of the N. F. P. A. and other organizations, and that such changes as seemed necessary and could properly be made in the fire code to avoid conflicts with the new safety code would be made. In return the Bureau of Standards was to cooperate with the N. F. P. A. 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 recent 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.

The Workmen's Compensation Service Bureau has also given valuable assistance by examining and criticizing the early drafts of the code.

A large number of 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. Many differences of opinion, of course, developed in these conferences, but it has been possible to secure approval of nearly all the rules by a very large majority of those participating in the conferences. It is hoped that further informal conferences soon to be held and the final formal conference in Washington will bring about a still greater degree of unanimity respecting those rules about which difference of opinion still exists.

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 with 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 chief energies 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 conference with operators, workmen, inspectors, and the State commissions, it is believed that we shall obtain full information 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. Criticism is invited of

the proposed rules contained in this publication and suggestions for their improvement, either by way of changes or additions. 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 notes on the rules. The intent of the rules will thus be better understood and criticisms will be correspondingly more valuable.

The thanks of the Bureau are extended to the very large number of persons 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 when finally completed will justify the large amount of time given to it by our conferees.

S. W. Stratton,
*Director.*

April 26, 1915.

# PLAN AND SCOPE OF THE PROPOSED NATIONAL ELECTRICAL SAFETY CODE

The attention of the Bureau was drawn several years ago to the need of a national safety code for electrical practice. Relatively few companies possessed printed sets of operating rules, and most of these were far from complete. There were no generally accepted construction rules framed from the standpoint of the life hazard, although the electrical code (for fire prevention) contained some rules bearing more on life hazard than on fire hazard.

These rules have exerted a powerful influence toward securing better electrical construction and reducing the fire hazard, and it was obvious that if a life hazard code could be formulated and maintained as successfully and adopted as generally as the fire code has been it would have a potent and salutary influence in unifying practice and reducing accidents. It was evident, however, that the preparation of such rules in a form that would be adequate and satisfactory would be no easy task. They should include operating rules for employers as well as for employees and construction rules for generating stations and substations, transmission and distribution lines, and the great variety of electrical machinery and apparatus which utilizes electricity. To prepare a single reasonably complete code that could be adopted and administered by State industrial commissions, public-service commissions, and municipal officials, and also used by the casualty insurance interests and which might be as generally accepted as the national electrical fire code has been appeared to be in the highest degree desirable. The alternative would be different rules in different States and cities, and then perhaps after years of confusion some unifying influence would bring order out of chaos, as was done some years ago with the fire code.

### PLAN OF THE WORK

The plan followed in the work was outlined in an announcement made at the Chicago convention of the National Electric Light Association in 1913 before the work was undertaken. The rules in force in various European countries were studied and the books of rules in use by operating companies in this country

were collected and examined. A study of the technical papers and reports of committees of engineering societies added substantially to the available material. All this enabled a first draft of a set of rules, in four parts, to be prepared for discussion and criticism.

The fourth part of the code, which contained a complete set of operating rules, was issued last August in a preliminary edition as Bureau Circular No. 49. Several thousand copies were distributed for examination, and several hundred letters were received in response to the Bureau's invitation for criticism. During the past three months the revision of these rules has been carried out in conjunction with the accident committee of the National Electric Light Association, and they are about to be republished in the second edition of Circular 49. Because the study and revision of these rules has been so thorough, they have been detached for the present from the three parts of the code which have to do with construction and installation. When the latter are completed and ready for use, they will be published together with the operating rules, the latter being part 4 of the complete code.

The construction rules as revised to date after many informal conferences and discussions are contained in this circular.

## ARRANGEMENT OF THE CODE

The numbering of the sections and of the rules is on the decimal system. The definitions bear numbers below 100. The rules on stations are divided into 9 sections, and 10 numbers are reserved for each section, although there are less than 10 rules in most of the sections. Thus rule 111 is in part 1, section 11, and the second rule of the section, the first being 110. The rules on overhead and underground lines are numbered from 200 up, the rules on utilization equipment are numbered from 300 up, and the rules on operation are numbered from 400 up. There are 65 rules in part 1, 49 in part 2, 63 in part 3, 116 in part 4, 293 in all. Additional rules may be added to any section in successive revisions without disturbing the numbering of the present rules. Each of the four parts is as nearly complete in itself as possible, in order to make it more convenient for use by different classes of users. This plan has made it necessary to duplicate in part 3 some of the rules of part 1. It is believed, however, that the objection to this

repetition is less than it would be to numerous references from one part to another.

### DISTINCTION BETWEEN STATION AND UTILIZATION EQUIPMENT

As stated in the introductory paragraph to the rules for stations, the rules apply to the electrical supply equipment of indoor and outdoor stations and substations and also to similar equipment, including generators, motors, storage batteries, transformers, and lightning arresters, when in factories, mercantile establishments, or elsewhere, provided they are in separate rooms or inclosures, under the control of properly qualified persons when such rooms or inclosures are inaccessible to others. Thus, the room or rooms in which the transformers, high-tension switches, and distributing switchboard are located in a factory are regarded as a substation, if under the charge of a qualified person, and subject to the rules for stations. On the other hand, the electrical wiring, motors, switches, and other equipment distributed about a factory or other building where employees generally have more or less access to it is regarded as utilization equipment.

The rules for utilization equipment apply to circuits and apparatus at not over 750 volts. Anything of higher voltage inclosed in rooms not accessible to employees generally will come under the rules for stations. Anything of higher voltage than 750 not so inclosed and accessible to others than properly qualified electrical operators must in addition to complying with the rules for stations and such of the utilization rules as apply, have all live parts incased in permanently grounded metal conduit or cases, or otherwise guarded to prevent access or unsafe approach by any person to the live parts.

### EXISTING INSTALLATIONS

The rules of parts 1, 2, and 3 apply, of course, to all new installations, unless modified for special reasons by the proper administrative authority. The question as to what extent they should apply to existing installations has been carefully considered. Obviously, if they did not apply at all to existing installations, they might have very little influence for many years to come.

The statement made in regard to this question is in the introduction to the several sections of the rules.

It is not expected that expensive changes will be made in existing equipment in order to comply with the rules, except in so far as it is necessary to do so to remove a source of serious danger. But in most cases grounding of machine frames, instrument cases or conduits, or erecting of suitable guards (where exposed live parts require it) can be done at substantially the same expense as though it were new equipment, and in all such cases it is expected that it will be done within some reasonable time.

## ENFORCEMENT OF THE RULES

There is so much interest in the subject of safety and so many managers are anxious to have their employees properly protected, it is believed that in many cases the rules will enforce themselves. If the State commissions and city administrative officers can provide intelligent and thoroughly competent inspectors, so that their inspections will have to some extent an educational value, the administration of the rules ought to be relatively simple. When force has to be applied, it can be done far easier if the administration of the rules is intelligent and reasonable and compliance is generally a willing one. It is hoped that such intelligent and competent inspection may be secured, and the Bureau of Standards will do all it can to assist commissions and municipalities who wish to give this kind of inspection.

Another important question in the administration of the rules is that of uniform interpretation by the people who are expected to comply with the rules and by the inspectors and others who administer them. In this edition of the rules a series of explanatory notes has been included, the notes occupying about as much space as the rules. The primary purpose of the notes is to assist in understanding the rules and their application, and they contain a good deal of interesting matter. It has been suggested to the Bureau that a textbook on safe construction and operation is much more needed than a set of rules. It is hoped that the notes to the rules, as they will be expanded in the later publication, will in connection with the rules fulfill to some extent the function of such a textbook. We shall be greatly pleased to receive suggestions as to what additional material should be put into the notes.

### DISTINCTION BETWEEN "SHALL" AND "SHOULD"

Many of the rules are put in the mandatory form by the use of "shall"; others are intended as strong recommendations, "should" being used to indicate that fact. "Should" is often used where it would be proper to require a certain thing of some companies, but not of all. In some cases "it is recommended that" are the words used. It was thought far better to make the rules reasonably complete, with some of them not mandatory, than to cut out all that could not properly be made mandatory generally. If the attempt had been made to make everything absolutely required, there would necessarily have resulted either a very incomplete safety code, or one that could not be enforced, or one that would work serious hardships in very many cases. It seems far better, particularly in the early history of such a code, to regard it as an educational and helpful influence quite as much as a code to be rigidly enforced.

### INTRODUCTION OF THE CODE

It is the hope of the Bureau of Standards that when the code has been revised once more and approved by the Washington conference and republished, it may be adopted very generally and with the minimum of changes by individual States or cities. It is suggested, however, that the first year may be made a trial year, during which the companies, inspectors, and commissions may become thoroughly acquainted with its practical operation, and that it be not enforced in any strict sense until after the first year. We believe that if the utilities and other companies coming under it are invited to try out the code, to comply as well as they can, to report wherein it is not satisfactory, and to assist in the effort to remedy its defects by revision at the end of the first year, far better results will be attained in the end than if it is made compulsory at the start. Some commissions and cities might delay adopting it formally if a strict enforcement were expected from the beginning, whereas they might be entirely willing to adopt it at once in the experimental way suggested. It is believed that this plan will secure the fullest cooperation of all interests concerned, which is much to be desired.

## DEFINITIONS OF SPECIAL TERMS

### ALPHABETICAL LIST OF DEFINED TERMS

## DEFINITIONS OF SPECIAL TERMS

The following definitions give the meanings of the terms occurring in these rules.

Terms not defined will be understood to have their usual meanings.

1. **Electrical supply equipment** means any equipment which produces, modifies, regulates, controls, or safeguards a supply of electrical energy. The supply equipment used in connection with signaling systems when operating below 150 volts is not included.

2. **Electrical supply station** means any building, room, or space within which is located electrical supply equipment.

The term includes generating stations and substations, and dynamo, storage-battery, and transformer rooms.

3. **Electrical supply lines** means those conductors and their necessary supporting or containing structures which are located entirely outside of buildings and used for transmitting supply of electrical energy. Telephone and other signal lines are not included.

4. **Signal lines** means lines for public or private signal service and devoted exclusively to the transmission of signals or intelligence, which operate at not exceeding 400 volts above ground or between any two points of the circuit, and the transmitted energy of which does not exceed 50 watts. Below 50 watts 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.

5. **Utilization equipment** means those devices and their wiring which utilize electrical energy for mechanical, chemical, heating, lighting, testing or similar purposes, and are a part neither of supply equipment nor of supply lines.

6. **Approved** means that a material or device has been subjected to examination or test and found to comply with these rules and with other nonconflicting accepted standards which apply for any given purpose.

The approval must state the purpose for which approval is given, must be of record, generally published, and issued either by the Underwriters' Laboratories or by some other properly qualified body.

7. **Voltage** means, in general, the effective voltage of the circuit concerned, except that in a 3-wire circuit with grounded neutral (either d. c. or low voltage secondary a. c.), the voltage is the effective voltage between either side and the neutral. Each such 3-wire circuit is considered as the equivalent of two 2-wire circuits.

When one circuit is directly connected to another circuit of higher voltage, both are considered as of the higher voltage unless the circuit of lower voltage is effectively grounded.

Direct connection implies electrical connection as opposed to connection merely through electromagnetic or electrostatic induction.

In two-phase or three-phase systems the voltage is the maximum effective voltage between phase wires.

8. **Circuit** means a conductor or system of conductors through which an electrical current may flow.

9. **Grounded** means connected to earth, either intentionally or accidentally.

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 that no harmful voltage can exist between the object so grounded and neighboring exposed conducting surfaces in good contact with earth.

11. **Manual** means operated by hand.

12. **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.

13. **Alive or live** means electrically connected to a source of potential difference, or having a potential different from the earth.

14. **Dead** means free from any electrical connection to a source of potential difference, and not having a potential different from the earth.

15. **Current carrying part** means a part intended to be connected in an electric circuit to a source of voltage, or to have a potential different from the earth.

16. **Substantial** means so constructed and arranged as to be adequate for the service it is to perform and secure from corrosion or other injury.

17. **Cutout** 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 load or voltage.

18. **Switch** means a device for opening or closing a circuit manually or by means of a suitable mechanism. In these rules a switch will always be understood to be manually operated unless otherwise stated.

A disconnector means any switch which is not designed to safely open a loaded circuit.

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. **Qualified or authorized persons** means persons properly qualified or authorized to perform specified duties under the conditions existing. To qualify as such, the person must have demonstrated his ability before a competent examiner or an established examining body.

20. **Guarded** means covered, shielded, fenced, inclosed or protected by means of metal or insulating covers, barrier rails or screens, mats or platforms to remove the liability of dangerous contact or unsafe approach by persons or objects to a point of danger.

21. **Exposed** means that an object or device can be inadvertently touched or approached nearer than a safe distance by any person. Objects neither effectively isolated nor suitably guarded.

22. **Accessible** means that an object or device can be safely reached by any person in his ordinary pursuits.

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

24. **Conductor** means any electrically conducting material, but ordinarily refers in these rules to a metallic conducting material, such as a wire or cable, used for the purpose of conveying electrical current.

25. **Insulated** means separated from other conducting surfaces by an approved 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 approved 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 clothing, guards, rods, and other safety devices) means that a device, when interposed between a person and current carrying parts, assures the person making use of it against electric shock from the current-carrying parts with which the device is approved for use—the opposite of conducting.

27. **Line conductor** means one of the conductors carried by, extending along the direction of the pole line.

28. **Lateral conductor** means a conductor in pole-line work, extending in a general horizontal direction approximately at right angles to the general direction of the pole line.

29. **Vertical conductor** means a conductor in pole-line work, extending in the general vertical direction of the pole structure.

30. **Pole face** means that side of a pole on which cross arms are attached, or if such cross arms are on both sides, that semicircumference which is so designated by the utilities owning or operating the pole.

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

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

CONTENTS

## GENERAL PROTECTIVE REQUIREMENTS

### SCOPE OF THE RULES

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

The rules apply fully to all new installations except as modified by the proper administrative authority. They apply to existing installations—(*a*) in extensions and reconstruction, except where for special reasons this is impracticable, (*b*) in cases of serious danger that can be obviated by conforming to the rules, (*c*) in the placing of guards and grounding of parts for the protection of employees, where the expense is not substantially greater than would be required for providing such protection for new equipment.

The time allowed for compliance with (*b*) and (*c*) will be fixed by State or municipal administrative authorities.

### 10. PROTECTIVE ARRANGEMENTS OF STATIONS

**100. General Requirement.**

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

(*a*) They shall be used for no hazardous process except production of a supply of electrical energy.

(*b*) They should be free from inflammable gas and flyings; indoor stations should be dry and well ventilated.

(*c*) In out-door stations or stations in wet tunnels or subways all live parts of equipment should be enclosed in tight metal cases, or otherwise properly protected.

Conductors not in conduit should be on suitable insulators and otherwise properly guarded or isolated by elevation.

**101. Illumination.**

(*a*) Rooms and spaces shall have good artificial illumination. Arrangements 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 safely accessible points.

Ladders do not provide safe means for reaching lamps which are above live or moving parts or over 15 feet above the floor.

(*b*) A separate emergency source of illumination from an independent generator, storage battery, gas mains, or other suitable source shall be provided in every station where an attendant is located.

It is recommended that this emergency source be permanently in use where practicable.

**102. Enclosing Walls and Ceilings.**

Rooms and spaces shall be so arranged as to prevent entrance of unauthorized persons or interference by them with equipment inside, and when entrances are not under observance of an authorized attendant they shall be kept locked.

(*a*) Where the station occupies only a portion of a building, or is located out of doors, a substantial enclosing fence, screen, partition, or wall of suitable height and construction shall be provided at all sides of the equipment.

(*b*) Above all equipment, substantial roofs or ceilings shall be provided, except above outdoor substations where the equipment is suitably enclosed or guarded to withstand rains and flying or falling objects.

**103. Floors, Floor Openings, Passageways, Stairs.**

(*a*) Floors shall be level and afford secure footings.

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 should provide at least 6½ feet head room.

(*c*) All floor openings over 2 feet deep, and all stairways or raised platforms over 4 feet high (except loading platforms) shall be provided with approved 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 openings in floors over 6 feet deep, the edges of all raised platforms over 6 feet high, and the backs of all stairway treads should be provided with suitable toe boards.

**104. Exits.**

Each room or space and each working space about such equipment shall have safe means of exit which shall be kept clear of all obstructions.

Where practicable there shall be at least two separate exits from each room, inclosure, platform, or passageway exceeding 10 feet in length.

**105. Fire Appliances.**

Each room or space where an operator is in attendance shall be provided with adequate approved fire extinguishing appliances, located conveniently and rendered conspicuous by suitable marking. Any such appliances which can not be safely used on live parts should be plainly and conspicuously marked with a warning to that effect.

## 11. PROTECTIVE ARRANGEMENTS OF EQUIPMENT

**110. General Requirement.**

(*a*) All electrical supply equipment shall be of suitable design and construction, and adequate for the work to be preformed, and so installed and maintained as to reduce the life hazard as far as practicable.

(*b*) It is recommended that equipment comply, when new, with the standardization rules of the American Institute of Electrical Engineers.

**111. Inspections.**

Electrical supply equipment with its associated guards and appliances (*a*) shall comply with these safety rules before being placed in use; (*b*) shall thereafter be systematically examined, inspected, cleaned, and any defects recorded on the station log.

**112. Irregularly-Used Equipment.**

Irregularly used equipment or wiring maintained for future service should be periodically inspected to determine whether it is fit for service. Defective equipment shall be put in good order or permanently disconnected. Defective wiring shall be removed.

**113. Protective Grounding.**

(*a*) GROUNDING METHOD.—All lightning arrester grounding, and all grounding of circuits, equipments or wire runways which are intended to be a permanent protective measure shall be made per-

manent and effective and shall be so arranged that there is no appreciable passage of current over the ground connections.

To secure permanent and effective grounding the grounding methods specified in Appendix A, or other equivalent means should be employed.

(*b*) GROUNDING NONCURRENT CARRYING METAL PARTS.—All exposed noncurrent carrying metal parts of elecrtical supply equipment (such as frames of generators, motors, and switchboards, and cases of transformers and oil switches) shall be permanently grounded (1) if operating at over 150 volts to ground, or (2) if in hazarduous locations.

Hazardous locations include those where dampness, explosives, inflammable gas, or flyings exist. They also include those where exposed grounded surfaces (such as metal frames or other machines, plumbing fixtures, concrete or earth floors or walls) exist within reach of persons while touching the metal parts under consideration. Usually grounded surfaces within 3 feet horizontally from the parts considered and within 7 feet vertically from the floor are considered within reach.

(*c*) EXCEPTIONS.—Exposed noncurrent carrying metal parts of electrical supply equipment operating on series or direct current grounded circuits may, where necessary, be left ungrounded, provided that suitable permanent insulating barrier guards, and insulating floors, platforms or mats are used, so that no person can inadvertently come in contact with such ungrounded parts while he is touching or standing upon any grounded surface (including floors not of insulating material, metal fixtures, and frames or cases of other equipment). Under such conditions the frames shall be made inaccessible to other than qualified persons, and suitably insulated from the ground.

**114. Working Space about Electrical Equipment.**

Adequate working space with secure footing shall be maintained about all electrical supply equipment which requires adjustment or examination during operation. Moving parts in these spaces shall be provided with approved barrier guards.

Working spaces about live parts over 150 volts to ground shall be made inaccessible to other than authorized attendants by the use of suitable barriers when necessary.

The spaces shall be so arranged as to give the authorized attendants ready and safe access to all parts requiring attention, and

should, where practicable, provide the following minimum working spaces:

(*a*) If there are exposed live parts up to 750 volts on one side, the minimum width should be 2½ feet; above 750 volts, at least 3 feet.

(*b*) If there are exposed live parts up to 750 volts on both sides, the minimum width should be 3 feet; above 750 volts, at least 5 feet.

(*c*) All working spaces shall have safe exits provided. When the space is narrow and exceeds 10 feet in length, it is recommended that exits shall be provided at both ends.

**115. Guarding Live Parts.**

Protection shall be provided for persons near otherwise exposed ungrounded current carrying parts of electrical supply equipment (such as the terminals of generators, and motors, bus bars, and other conductors), operating at over 150 volts to ground and not effectively isolated by elevation, as follows:

(*a*) Where the working space about electrical equipment is less than that specified in rule 114 (*a* and *b*), 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 within reach shall be provided with suitable insulating platforms or mats.

Inclosures may consist of casings or suitable insulating coverings. Insulating coverings of conductors should be depended upon only when very substantial, thoroughly dry, and containing no noninsulating flame-proofing compound.

Barriers may consist of horizontal or vertical strips placed in front of live parts, or of closely spaced partitions between the live parts, extending beyond the latter on the exposed sides.

Where covers, casings, or barriers must at any time be removed while the parts they guard are alive, they should be of insulating material.

(*b*) Where the specified working spaces are provided and the live parts are not guarded by inclosures or barriers, the insulating platforms or mats shall always be provided.

(*c*) Where the live 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 insulating material and so spaced from the live parts as to prevent persons from approaching nearer than three times the needle point sparking distance of the voltage concerned.

**116. Isolating Live Parts by Elevation.**

Current carrying parts need not be guarded if they are maintained at the following distances above the floors: Column 1 refers to distances to be provided over floors to which unqualified persons sometimes have access, and column 2 where qualified persons only have access.

| Voltage of conductors | Column 1 | Column 2 |
|---|---|---|
| | Feet | Feet |
| 150 to 750 | 8 | 7 |
| 750 to 7500 | 9 | 7 |
| 7500 to 27 000 | 10 | 8 |
| 27 000 to 47 000 | 11 | 8½ |
| 47 000 to 70 000 | 12 | 9 |
| 70 000 to 100 000 | 13 | 10 |
| 100 000 up | 14 | 11 |

**117. Identification.**

All electrical supply equipment and circuits shall be adequately identified by position, color, number, name plate, label or design, as to voltage, intended use, and proper connections.

All connections shall be arranged in a simple and orderly manner.

## ROTATING EQUIPMENT, STORAGE BATTERIES, AND TRANSFORMERS

### 12. ROTATING EQUIPMENT

THIS INCLUDES GENERATORS, MOTORS, MOTOR-GENERATORS, AND CONVERTERS

**120. Speed-Control and Stopping Devices.**

(*a*) Prime movers driving generating equipment should be provided with automatic speed-limiting devices (in addition to their governors) where harmful overspeed can otherwise occur.

(*b*) Separately excited d. c. motors and motor generators, and converters where it is possible for them to be driven from the d. c. end by a reversal of current, shall be provided with speed-limiting devices.

(*c*) Where the speed control of direct current motors is accomplished by varying the field resistance, the field rheostats shall be arranged with no voltage releases or other devices so that the motor can not be started under dangerously weakened field.

(*d*) Stopping devices which can be operated from locations convenient to machine operators should be provided for prime movers or motors driving generating equipment.

(*e*) Where speed-limiting and stopping devices are electrically operated the control circuits by which such devices are actuated shall be in conduit.

**121. Deteriorating Agencies.**

Suitable guards or enclosures shall be provided to protect current carrying parts, insulating of leads, balancing 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 other similar injurious agents exist.

**122. Field Break-Up Switches.**

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 and to protect persons while adjusting them.

**123. Protecting Shaft Ends, Pulleys, Belts, and Other Moving Parts.**

Pulley wheels, belts, and shaft ends projecting through bearings, revolving armatures, and other moving parts should either be entirely inclosed in suitable casings, or otherwise adequately guarded by rails or barriers, to keep persons from harmful contact with those parts.

**124. 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 150 volts to ground, that operators need not touch such parts unless standing on the mat or platform. For parts above 750 volts, suitable inclosing or barrier guards shall be provided, in addition to mats or platforms, so arranged that the operator can not inadvertently touch at the same time these live parts and any neighboring grounded parts.

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.

(*b*) Where machine frames, such as those of series arc light generators or high voltage d. c. railway generators, are necessarily ungrounded, suitable insulating floors, mats or platforms shall be so placed on floors surrounding that no person can touch the machine frame unless standing on the floor, mat or platform.

Where machines are mechanically coupled together, and the operator can touch the frames of more than one at a time, the frames of all shall be grounded, unless they are bonded together electrically and surrounded by insulating mats or platforms.

Exciters direct connected, and auxiliary circuits electrically connected with generators or other machines over 750 volts to ground, with frames ungrounded, shall be installed and protected as machines and circuits of the same voltage as that of the machine for which they are auxiliaries.

**125. Grounding for Noncurrent Carrying Parts.**

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 and with the exceptions therein provided.

### 13. STORAGE BATTERIES

**130. Isolation.**

Storage batteries exceeding 50-kwh. capacity or 150 volts to ground shall be made inaccessible to other than properly qualified persons by inclosure in a separate room.

**131. Ventilation.**

Rooms containing storage batteries shall be so ventilated as to prevent accumulation of inflammable gas.

Communication of drafts to other rooms should be prevented.

**132. Covers.**

Suitable covers or other devices should be arranged to minimize the escape of electrolyte from cells during charge.

**133. Insulating Supports.**

Individual cells shall be separately supported by suitable insulators.

Suitable drainage shall be provided beneath cells.

**134. Guarding Live Parts.**

The arrangement of cells shall be such that no two current carrying parts between which a voltage exceeding 150 exists shall be closer than 3 feet if exposed to accidental contact.

The working space about cells operating at over 150 volts to ground should be provided with a suitable insulating platform.

Up to 150 volts to ground, insulating stools are usually sufficient protection.

**135. 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, should be used.

**136. Acid Proofing.**

Conductors about batteries, if of such material or so located as to be liable to corrosion, shall have suitable protective coverings or coatings.

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

**140. Oil-insulated Transformers.**

Oil-insulated transformers and similar equipment (above 20 kw. in any unit or 50 kw. in any group), should where practicable be placed in a drained and ventilated room of fire-resistive construction. It is recommended that arrangements be provided where practicable, so that the equipment can be entirely disconnected from all sources of energy and quickly drained of oil from a point outside the room.

Such rooms should contain no other equipment than controlling equipment, should be subdivided by fire-resistive walls as much as practicable, should be drained to a safe point outside, and should have all door or window openings communicating with or exposing other rooms, fitted with tight fire-resistive doors or windows and oil tight sills of suitable height.

**141. Current Transformer Secondary Circuits.**

Current transformer secondary circuits, including those supplied from constant current and instrument transformers shall (except where supplying relays only) be provided with means for short circuiting them which can be safely connected while the primary is energized, and which are so arranged as to permit the removal of any instrument or other device in such circuits without opening the circuits.

Where primaries are above 7500 volts, secondaries, unless otherwise adequately protected from disturbance, should be in permanently grounded conduit.

**142. Grounding Low-voltage Circuits of Instrument Transformers.**

The low-voltage circuits of all instrument transformers shall be permanently grounded at one secondary terminal, 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 this low-voltage circuit from others with which it is associated, but which are protected by ground connections.

**143. Guarding or Isolating Live Parts.**

(*a*) Unless effectively isolated by elevation as required by rule 116, all leads and other current carrying parts above 7500 volts shall be guarded by suitable permanent covers, screens or inclosures, entirely surrounding the parts where otherwise exposed.

If not of grounded metal, such guards should prevent approach of persons to the live parts nearer than three times the needle point sparking distance.

(*b*) Unless effectively isolated, leads and other live parts below 7500 volts, but above 150 volts, shall be guarded either by complete covers or inclosures, or the surrounding floors shall be provided with suitable permanent insulating platforms or mats of substantial construction, providing good footing. Mats or platforms, if used, should surround the live parts on all accessible sides to such a distance that the operator can not readily touch the live part, except while standing on the platform or mat.

Guards shall be provided for all live parts above 750 volts, even where insulating floors or mats are provided, to prevent persons from inadvertently touching the live parts and other conducting surfaces at the same time.

**144. Grounding Transformer Cases.**

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

## WIRING, AND PROTECTION AND CONTROL EQUIPMENT

### 15. CONDUCTORS

**150. Protection in General.**

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

Grounded conductors and ground wires shall be arranged without automatic cut-outs interrupting their continuity.

Conductors of circuits supplied from one or more sources of electrical energy shall be provided with suitable switches to safely disconnect them from all such sources.

(*b*) MECHANICAL AND THERMAL PROTECTION: 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.

Where exposed in open construction to danger of arcing of other conductors, or to any combustible material, suitable substantial noncombustible outer covering shall be employed for insulated conductors.

Bare conductors shall be sufficiently spaced to prevent maintenance of arcs between them.

Large uninsulated conductors, liable to be torn from their supports by the stresses to which they are subjected (by their weight or 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.

**151. Isolation by Elevation.**

All conductors over 750 volts, and ungrounded bare conductors at all voltages shall be isolated by elevation (as required by rule 116), so that no person can inadvertently come in contact with them, unless guarded in accordance with rule 152.

**152. Guarding Conductors.**

USE OF INCLOSING CASINGS.—For inclosing insulated conductors approved permanently grounded metal conduit or grounded metal

sheathing shall be used, except that for conductors below 750 volts other ducts, runways, or compartments of suitable fire-resistive materials may be used, if containing no exposed combustible material. In damp places, conduit, ducts or runways must be made waterproof and be provided with suitable means for draining off condensation.

(*a*) CONDUIT ABOVE 750 VOLTS.—Conductors operating at over 750 volts (unless separately supported and effectively isolated by elevation or by installation in suitable compartments or screens, as in paragraph (*c*) or (*d*)) shall be approved metal sheath cable, run in metal conduit or suitable fire-resistive duct or compartment, and with the metal sheath permanently grounded; or other suitable covering may be used in dry locations, run in suitable grounded metal conduit or insulating duct. The conduit or duct shall provide a smooth runway, with smooth outlets.

(*b*) METAL SHEATH CABLE OUTLETS ABOVE 750 VOLTS.—The insulation of the several conductors where leaving the metal sheath at outlets shall be thoroughly protected from mechanical injury and moisture by means of a pot head or equivalent method. The metal sheath (and metal conduit, if used) shall be made electrically and mechanically continuous with the metal casings of all fittings in which conductors are laid, unless these fittings are so isolated as to be inaccessible to unauthorized persons.

(*c*) OPEN CONDUCTORS ABOVE 7500 VOLTS.—Where open wiring above 7500 volts is necessarily brought closer to the floor line than the clearances required for isolation by elevation, the conductors shall be guarded by permanent screens or inclosing partitions while the conductors are alive.

(*d*) OPEN CONDUCTORS BELOW 7500 VOLTS.—When open insulated conductors between 750 and 7500 volts, or any open bare conductor at any voltage between 150 and 7500, is necessarily brought closer to the floor line than the clearances required for isolation by elevation, they shall be guarded by permanent screens or inclosing partitions. Where persons at any time remove or pass such barriers, while conductors are alive, all conducting floors, walls, machine frames, and similar surfaces, within 7 feet below the conductors or 3 feet horizontally from them, shall be covered with suitable insulating platforms, mats or covers.

**153. Guarding in Hazardous Locations.**

(*a*) Conductors in locations where inflammable gas exists shall be in metal conduit or metal-sheathed cable. All fittings and outlets of each conduit and cable shall be electrically and mechanically continuous with the conduit or metal sheath.

(*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.

**154. Pendants and Portables.**

Pendant conductors shall not be installed where they can readily be moved so as to bring them in contact with other live parts.

Portable conductors shall be attached to fixed wiring only through separable attachment plugs which will disconnect all poles by one operation.

**155. Temporary Wiring.**

No fixed wiring shall be installed for temporary use, which is not in compliance with these rules unless it is under constant competent supervision while it or neighboring wiring is alive and accessible to any person.

**156. Taping Bare Ends and Joints.**

Bare ends and joints of insulated conductors unless otherwise adequately guarded shall have equal insulating covering with other portions of the conductor. This applies to temporary as well as to permanent construction. Such parts of conductors shall be installed only where supported on insulators or located in junction boxes, outlet boxes, or similar points in conduits or other casings.

## 16. SWITCHES, FUSES, AND OTHER CUTOUTS; CONTROLLERS, AND OTHER CONTROL DEVICES

**160. Accessible and Indicating.**

All switches, automatic cutouts, controllers, starting rheostats, and other control devices shall be readily and safely accessible to authorized persons. They shall be so arranged or marked as plainly to indicate 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, and so that gravity can not close them.

**161. Hazardous Locations.**

When necessary to install switches or other control devices in locations where inflammable gas or flyings exist, they shall be inclosed in explosion-proof permanently grounded metal cases.

**162. Where Switches are Required.**

(*a*) Suitable switches shall be inserted in all circuit leads (except a grounded conductor) to generators, motors, transformers, and all outgoing supply circuits.

(*b*) Suitable means shall be provided (such as switches with locks or blocks, and tags) so that all electrical equipment and outgoing circuits can be prevented from being made alive and from starting when persons are working on or about them, unless all live and moving parts are so guarded as to render this unnecessary.

**163. Character of Switches to Use.**

(*a*) CAPACITY.—Switches other than disconnectors shall be able to interrupt safely the largest currents to which the switches are limited by the design of the system, or by automatic cutouts in circuit.

Where used only as disconnectors to interrupt unloaded circuits or to interrupt a limited part of the load which they may be at times called upon to carry, switches shall be plainly marked with warning against opening while carrying current in excess of the safe limit.

Interlocking arrangements are desirable to prevent opening of such switches under loads beyond their capacity.

(*b*) LOCKING.—Switches 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.

(*c*) AIR BREAK.—Unless a switch operating on a circuit above 750 volts makes an air break, there shall be installed between it and the source of energy supply a suitable air break manual disconnector having an air gap suitable for the operating voltage of the circuit.

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

**164. Where Automatic Cutouts are Required.**

All circuit leads to motors, transformers, and all outgoing circuits shall be protected against excessive current by the design of the system or by suitable automatic cutouts, except as noted in rule 150 (*a*). Leads from generators and storage batteries should also be protected by such means, if practicable.

**165. Arrangement of Automatic Cutouts.**

(*a*) DISCONNECTION BEFORE HANDLING.—Fusible cutouts shall be arranged so that: (1) The exposed current carrying parts can not be touched until the cutout is disconnected from all sources of energy; or (2) so that the cutout can be disconnected before being handled, by a suitable switch in series; or (3) safely handled by means of the portable insulating appliances provided for the purpose.

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

(*b*) SHIELDING FROM ARCS.—Fuses and circuit breakers shall as far as possible be so located and shielded that persons will not be burned by their operation.

**166. Suddenly Moving Parts.**

Parts which may move suddenly, such as handles or levers of circuit breakers, shall be so guarded or isolated that persons in the vicinity can not be struck by them.

**167. Grounding Noncurrent Carrying Metal Parts.**

Exposed noncurrent carrying metal parts of switch and fuse cases, levers, and other similar parts to which leakage can occur from live parts shall be permanently grounded according to the provisions of rule 113.

**168. Guarding Live Parts of Switches and Automatic Cutouts.**

(*a*) ABOVE 750 VOLTS.—Except as provided in (*d*) below, for switches requiring only infrequent attention, and located in inclosures from which even the operator is normally excluded, all switches interrupting circuits over 750 volts, shall be operated

through remote control mechanisms or be provided with suitable casings safely protecting the operator from danger of contact with current carrying parts. The control devices shall indicate whether switches are open or closed. All automatic cutouts not suitably isolated by elevation, shall be provided with suitable casings.

(*b*) BELOW 750 VOLTS.—All switches interrupting circuits under 750 volts shall be operated through remote control mechanisms or be provided with suitable casings safely protecting the operator from danger of contact with current-carrying parts; or the switches shall be provided with insulating handles and insulating guards, 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.

(*c*) PLATFORMS OR MATS.—Where live parts of switches or automatic cutouts operating at over 150 volts to ground are not provided with inclosing guards, effective during ordinary operation or adjustment, suitable insulating floors, mats, or platforms shall be provided on which the operator must stand while operating the switches or adjusting automatic cutouts.

(*d*) WORKING SPACES ABOUT OCCASIONALLY EXPOSED LIVE PARTS.—Where switches, disconnectors, and fuses above 750 volts are ordinarily guarded by covers or inclosures, but must occasionally be operated without such protection, either by removal of the covers, or by entrance into inclosures, 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 *Feet* |
|---|---|
| 750 to 7500 | 1 |
| 7500 to 27 000 | 2 |
| 27 000 to 47 000 | 3 |
| 47 000 to 70 000 | 4 |
| 70 000 to 100 000 | 5 |
| 100 000 up | 6 |

## 17. SWITCHBOARDS

**170. Accessibility and Convenient Control.**

Switchboards shall have all switches so arranged that the points of control are quickly and safely accessible to the operator.

**171. Convenient and Safe Attendance.**

Switchboards shall have all instruments, relays, and other devices requiring reading or attention so placed that work can be readily performed from the working space without unsafe approach to any live parts.

No wires or devices shall be placed on or near switchboards so that operators examining or adjusting them need go nearer than 6 inches to exposed parts above 750 volts.

**172. Safe Location.**

Switchboards shall be so located that the operator will not be endangered by any live or moving parts of machinery or equipment located near the board.

**173. Necessary Equipment.**

Switchboards which control circuits connected to electrical supply equipment shall be equipped with such voltmeters, ammeters, ground detectors, and other indicating devices as will adequately show the operating conditions.

**174. Arrangement and Identification.**

Connections, wiring, and equipment of switchboards shall be arranged in an orderly manner, and all switches and other cutouts shall be plainly marked or labeled to identify the circuits of equipment supplied through them.

Switchboards shall have live parts which are ordinarily isolated or guarded, but which may occasionally require adjustment or repair during operation, so arranged that suitable portable covers or shields can be effectively secured about them to guard against all neighboring live parts.

Special marking shall be provided to distinguish connections on one circuit from those on another.

**175. Illumination.**

Illumination shall be provided for the entire switchboard so that adjustments may be safely performed and instruments clearly read.

**176. Spacings and Barriers Against Short Circuit.**

Switchboards shall have bare parts at different voltages on any panel reduced to a minimum, and these parts shall be effectively separated. 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 barriers that parts of different voltage will not be accidentally short-circuited by tools or other conducting objects.

**177. Protective Ground.**

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 safely connecting the parts being grounded to the ground connection.

**178. Grounding Frames.**

Switchboard frames should be permanently grounded under the conditions noted in rule 113.

**179. Guarding Live Parts.**

(*a*) INCLOSURE.—All switchboards operating at over 150 volts to ground and not effectively isolated by elevation (as per rule 116) shall be located away from passageways and (unless under constant attendance during operation) suitably inclosed or barriered to make them inaccessible to other than the authorized operator.

(*b*) MATS.—For the protection of the operator, where parts over 150 volts to ground are not otherwise guarded, suitable insulating floors, mats, or platforms providing good footing shall be so arranged that the operator must stand upon them in order to touch the live parts.

(*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.

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 current-carrying parts are exposed at either face or back of switchboards, ample working space shall be provided adjacent to them. If possible, these spaces should provide the distances specified in rule 114 (*a*) and (*b*).

When such working spaces can not be provided, suitable guards shall be arranged to protect the operator from contact with parts over 750 volts.

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

(*e*) PLUG-TYPE SWITCHBOARDS.—Plug-type switchboards should have no current carrying part exposed on face of boards, and plug connectors shall have all current carrying parts guarded as long as they are alive.

(*f*) INSTRUMENTS.—Metal cases of instruments 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 exposed current carrying parts above 7500 volts, except at times when occasionally left exposed by removal of covers or entrance into ordinarily unoccupied inclosures. For such parts (including busses in compartments and disconnectors) working space shall be provided complying with the requirements under 168 (*d*).

(*h*) EXITS.—Exits from working spaces about switchboards, from bus chambers, and similar locations, shall comply with rule 114.

### 18. LIGHTNING ARRESTERS

**180. When Required.**

Suitable lightning arresters shall be provided to protect outgoing ungrounded conductors connecting the supply equipment to overhead lines, in locations where lightning occurs.

**181. Type and Capacity.**

Each lightning arrester must be of suitable type, capacity, and adjustment for the circuit it is to protect.

**182. Disconnectors.**

Lightning arresters on circuits over 7500 volts, shall be so arranged, isolated, and equipped that they may be safely disconnected from conductors to which they are connected by air-break manual disconnectors, having break distance not less than four times the equivalent needle point spark gap of the voltage for which the arresters are set.

Such disconnectors, unless remotely controlled, shall have adjacent working space as required by rule 168 (*d*) for disconnectors generally.

**183. Location.**

Lightning arresters inside buildings should be safely spaced from all other equipment and from combustible parts of the building.

Arresters located inside buildings should be placed as near as practicable to the point of entrance of outside lines.

**184. Ground Wires.**

Ground wires shall be run as directly as possible and be of low resistance and ample carrying capacity.

**185. 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.

**186. Guarding Live Parts.**

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.

Lightning arresters shall be so arranged that necessary adjustments are possible (without unsafe approach to current carrying parts) through permanently grounded mechanisms or through the use of insulating appliances of suitable length.

Guarding shall comply with the provisions of rules 115 and 152.

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

CONTENTS

## OVERHEAD AND UNDERGROUND LINES

### SCOPE OF THE RULES

The following rules apply fully to all new installations of electrical supply and signal lines maintained in overhead or underground construction, except as modified by the proper administrative authority. They apply to existing installations, (*a*) in extensions and reconstructions, except where for special reasons this is impracticable, (*b*) in cases of serious danger that can be obviated by conforming to the rules, (*c*) in the placing of guards and grounding of parts for the protection of employees, where the

expense is not substantially greater than would be required to provide such protection in new construction.

The time allowed for companies to comply with (*b*) and (*c*) will be fixed by State or municipal administrative authorities.

These rules are not intended as complete specifications for overhead and underground line construction, but are intended to embody the most important features from the standpoint of safety to employees and the public. Construction should be made according to accepted good practice for the given local conditions in all particulars not specified in the rules. A list of specifications issued by various engineering societies, prepared for the purpose of promoting better and more uniform practice in construction, is given below. They are not, however, in all respects consistent with one another.

(*a*) N. E. L. A. Overhead Line Construction Committee—1914 Report, and Section 3 of the 1911 Report on the Joint Use of Poles, by Lighting and Telephone Companies.

(*b*) A. E. R. E. A. Specification for Overhead Crossings of Electric Light and Power Transmission Lines, 1913.

(*c*) Report of the Joint Committee on Joint Use of Poles, A. E. R. A., 1914.

(*d*) Report of the Committee on Power Distribution, A. E. R. A., 1914.

(*e*) The Standardization Rules of the A. I. E. E., 1914.

(*f*) Specifications for the Replacement and Reinforcement Inspection of Pole Lines, A. T. and T. Co., 1912.

(*g*) Specifications for Crossings of Wires or Cables of Telegraph, Telephone, Signal, and other circuits of similar character over Steam Railroad Rights-of-way, Tracks, or lines of Wires of the same class, Association of Railway Telegraph Superintendents, 1913.

NOTE.—The National Joint Committee on Overhead and Underground Line Construction (formed in 1914) represents a large number of interests, and its reports when issued will presumably supersede some of the above.

### 20. GENERAL REQUIREMENTS

**200. Design and Capacity.**

All electrical supply lines and equipment shall be of suitable design and construction and adequate for the service and con-

ditions under which they are to be operated, and so installed and maintained as to reduce the life hazard as far as practicable.

**201. 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.

**202. Inspections.**

(*a*) All new construction should be thoroughly inspected by a competent authorized person prior to placing it in service. Existing installations and protective guards and equipment shall be systematically inspected and, when necessary, subjected to tests to determine their fitness for service.

(*b*) Irregularly used lines and equipment, maintained for future service, shall be periodically inspected to determine whether they are fit for service. Defective equipment shall be put in good order or permanently disconnected. Lines temporarily out of use shall be maintained and inspected the same as if in regular service; or, if abandoned, they shall be removed.

**203. Records.**

Records should be maintained of repairs made to defective equipment, where the defects are such as to affect personal safety. The record should include the location and type of construction and equipment and the date and nature of repairs made.

**204. Isolation, Guarding, and Accessibility.**

(*a*) Conductors and other current carrying parts of electrical supply lines shall be arranged to promote safety to the general public and unauthorized employees by providing suitable guards or such clearances from the ground (or other spaces generally accessible) as to effectively isolate them from accidental contact by such persons.

Guards may be advisable in addition to isolation by elevation if latticed towers or stepped poles make access possible to children and other thoughtless trespassers.

(*b*) All parts shall be so arranged as to be readily accessible to authorized persons.

(*c*) Any ungrounded noncurrent carrying metal parts which are liable to become alive shall be so isolated or guarded as not to be exposed to unauthorized persons.

This includes metal-sheathed service cables, service conduits, metal fixtures, arc light suspension chains, and guys, but necessarily excludes metal poles, which (unless especially grounded) should always be considered as imperfectly grounded.

**205. Electrical Protection and Control of Circuits.**

Manual control, automatic overload protection, and protection against lightning or over-voltage from other causes, wherever installed, shall be in accordance with the requirements of the rules for Supply Stations so far as they apply.

**206. Grounding Circuits and Equipment.**

(*a*) All lightning arrester grounding, and all grounding of circuits, equipment, or wire runways, which is intended to be a permanent protective measure, shall be made permanent and effective and shall be so arranged that there is no appreciable passage of current over the ground connection.

To secure permanent and effective grounding the grounding methods specified in Appendix A, or other equivalent means, should be employed.

(*b*) Metal conduit, cable sheaths, frames, cases or hangers of equipment not effectively isolated or guarded from accidental contact of other than properly qualified workmen shall be permanently grounded, except metal conduit and cable sheaths inclosing conductors at not over 150 volts to ground and not exposed to probable contact with overhead conductors above 150 volts to ground.

Metal conduit containing underground metal-sheathed cable is considered as grounded by the sheath.

**207. Identification.**

All conductors and equipment of electrical supply and signal lines should be arranged to occupy definite positions throughout, or shall be so constructed, located, or marked as to provide (in conjunction with the diagrams if supplied) ready identification by employees authorized to work thereon. This does not prohibit systematic transposition.

## OVERHEAD LINES

### 21. CONSTRUCTION REQUIRED FOR CROSSINGS, CONFLICTING LINES, AND LINES ON THE SAME SUPPORTS

**210. Separation of Lines to Avoid Conflict.**

(*a*) Supply lines on different pole lines from signal lines should, where practicable, be so separated therefrom that the conductors of the higher line, in case it overturns, can not touch those of the other line or be separated by the width of a street, providing not less than two-thirds of the above distance.

(*b*) Any less clearance than the above, except at crossings with the angle greater than 15°, shall be considered as making the lines "conflicting."

**211. Arrangement of Lines when in Conflict or Carried on the Same Supports.**

(*a*) When conflicts occur between supply and signal lines, or between supply lines of different voltages, the higher voltage lines should be carried at the higher levels.

(*b*) Where, however, the lower voltage lines are carried at the same or higher level than the higher voltage lines their mechanical construction and supports shall be of such grade as to provide mechanical factors of safety not less than those required by these rules for the highest voltage lines concerned in the conflict (where carried at the higher level).

This rule holds where the supply and signal lines or the two sets of supply lines are carried on the same supports.

**212. Required Grades of Construction.**

Supply and signal lines when concerned in crossings, or conflicts, where carried on the same supports with other lines, or where carried through urban districts under the circumstances noted in the following table, shall have mechanical construction of the grade given in the corresponding column of the table. A is the higher grade and B the lower, specified in Rule 213. For grade E see Scope of the Rules (*g*).

TABLE 1

Grades of Overhead Construction

| Character of lines | Grades required | |
|---|---|---|
| | Urban districts | Rural districts |
| 1. Supply lines carried over steam railroads or other railways on private rights-of-way | A | A |
| 2. Supply lines above 5000 volts * when crossing over, or carried in conflicts, or on common poles with signal lines and at the same or higher levels | A | A |
| 3. Supply lines above 7500 volts when crossing over, or carried in conflicts, or on common poles, with supply lines below 7500 volts and at the same or higher levels | A | B |
| 4. Supply lines above 750 volts alone, or between 750 and 7500 volts in crossings, conflicts, or common use of poles with lines below 7500 volts, at any level | B | .. |
| 5. Signal lines over steam railroads, or other railways, on private rights-of-way | E | E |

* This limit is made lower than 7500 volts because of the supposed inability of telephone fuse protectors in general use to protect against voltages higher than 2500 to ground on constant potential A. C. circuits. It is claimed by some engineers that such fuse protectors afford ample protection up to 4000 volts to ground. This difference of opinion is largely due to insufficient experimental data. It is expected that further experimental results will be secured in the near future, and this limit may be raised if the experiments justify it.

(*a*) Urban districts means thickly settled communities (whether in cities or suburbs) where congested traffic occurs.

Rural districts means all other places, usually in the country, but in some cases within city limits.

(*b*) For cases where relative levels of supply and signal lines, or of two sets of supply lines, are different from those noted in the table, see rule 211.

(*c*) Service loops concerned in crossings, conflicts, or common use of poles are to be considered as line conductors of the same voltage classification.

(*d*) Constant current series lines of 7500 volts or less take the same voltage classification as constant potential lines of 5000 volts or less. Constant potential direct current lines of above 750 volts take the same voltage classification as constant potential alternating current lines above 5000 volts.

**213. Requirements for Construction and Maintenance of Lines Designated as Grades A and B in Table I.**

(*a*) Conductors of hard-drawn copper or aluminum (when unloaded) shall have normal sags not less than the values indicated in the tables of Appendix B for safe sags of such conductors. Conductors of soft-drawn copper (whether bare or insulated) shall have sags at least double that required for hard-drawn copper of the same size.

In computing the safe sags given in the tables of Appendix B provision has been made for a variation in temperature from 0° to 120° F. Suitable modification of these temperature limits should be made for localities in which the extreme range of temperature is greater or less than this.

(*b*) Poles or towers shall withstand (with the designated factors of safety of paragraph (*e*) below) the combined stresses due to their own weight, the wind pressure on the pole or tower, and the wire loading of paragraph (*d*) below. The wind pressure on poles or towers shall be assumed at 8 pounds per square foot of projected area for cylindrical surfaces and 13 pounds per square foot on the projected area of flat, solid, or closed structures, and on one and one-half times the projected area of latticed structures.

(*c*) Insulators, pins, and all other conductor attachments shall be capable of withstanding the mechanical loading due to the tension of conductors when properly secured in place and pulled (by loading or otherwise) to a tension equal to one-half the ultimate tensile strength of the conductors, but not exceeding 1500 pounds.

(*d*) In computing the factors of safety of poles, crossarms, and conductors, the most adverse conditions of mechanical loading to which it is assumed they will be subjected, is equal to the resultant of the dead weight of the wire, plus the weight of a layer of ice of one-half inch radial thickness combined with a wind pressure of 8 pounds per square foot on the projected area of the poles and ice covered wire at a temperature of 0° F. In addition to the above, it is assumed that supports for crossing spans shall be capable of resisting the twisting effort due to breaking one conductor at the

outer pin position of each crossarm supported. This conductor would be assumed to exert a pull of 1500 pounds with a lever arm equal to the distance to the next occupied pin position, while for a crossarm carrying but one conductor on one side of the pole the lever arm will equal the distance to the point of attachment of the crossarm to the pole.

(*e*) The ultimate unit stress for different materials used, divided by the allowable unit stress shall give at the time of construction or reconstruction not less than the following factors of safety for the two grades of construction designated respectively as A and B.

| | A | B |
|---|---|---|
| Wire, cables, and pins | 2 | 2 |
| Insulators, conductor attachments, guys | 2 | 2 |
| Structural steel | 3 | 2 |
| Reinforced concrete poles and crossarms | 3 | 2 |
| Wooden poles and crossarms | 4 | 2 |
| Foundations of poles | 3 | 2 |

With pole lines used in common by signal lines and by supply lines between 5000 volts and 7500 volts, Class B construction may be used provided the factor of safety in pins is increased to three and the pin is of a type which does not materially weaken the cross arm and is positively attached to the cross arm.

In calculating these factors of safety, the values of the allowable unit stresses shall be those given by reliable tests on samples of materials used, or values previously determined for similar materials.

(*f*) Wood poles and crossarms should be replaced when their factors of safety have decreased to one-half that required when new.

## 22. CLEARANCES OF CONDUCTORS AT CROSSINGS

### 220. Conductors Above Railways and Highways.

The clear space between the lowest overhead line conductors, guys, arc or trolley span wires, or overhead ground wires, and the heads of rails, crowns of streets, highways, alleys, or generally accessible spaces across or along which the former pass, shall not be less than given in Table 2, at 60° F. with no wind or other mechanical loading of the conductors or wires.

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TABLE 2

**Road Crossing Clearances**

Clear space 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, overhead ground wires, service loops | 0 to 7500 volts | 7500 and higher volts | Trolley contact wires and trolley feeders |
|---|---|---|---|---|
| Crossing above railroads handling standard freight cars | 25 | 25 | 25 | 21 (*a*) |
| Crossing or along streets or alleys in urban districts | 18 | 20 | 25 | 18 |
| Crossing or along streets or roads in rural districts (over the traveled way) | 18 | 20 | 25 | 18 |
| Crossings above spaces or ways accessible to pedestrians only | 10 | 15 | 20 | 18 |

(*a*) In many localities 22 feet is provided and considered good practice.

TROLLEYS OVER THEIR OWN TRACKS

| | |
|---|---|
| Where standard freight cars are handled | 22 |
| Where freight cars are not handled | 18 |

The clearances for trolley contact wires and feeders, where run under structures of elevated railways, above grade railroad or highway crossing bridges, and in subways or tunnels, will be governed by local conditions.

## 221. Conductors Crossing Others.

The clear space between the lowest overhead line conductor, guy, arc, or trolley span wire, or overhead ground wire, and any other conductor or wire over which the former crosses, shall not be less than given in Table 3 at 60° F. with no wind or other mechanical loading on the conductors or wires.

**TABLE 3**

**Wire Crossing Clearances**

The table gives the clear space in feet to be provided between conductors or wires named at the heads of columns and those at the side of the table when neither of the spans concerned exceeds 100 feet.

Conductors or lines operating at the voltages indicated at the heads of columns are to be installed above those to the left of the table, where a clearance is given, except as follows:

When the lines indicated to the left of the table provide such mechanical construction and factors of safety as are required of the lines at heads of columns (where normally crossing above them), then the former may be maintained in the higher position at a crossing when necessary.

| Voltage classification | Signal | 0 to 750 volts | 750 to 7500 volts | 7500 to 40 000 volts | Guys, span wires, overhead gr. wires, service loops |
|---|---|---|---|---|---|
| Signal (includ. cables and mess.) (*a*) | 2 | 2 | 4 | 6 (*b*) | 2 |
| 0 to 750 | ..... | 2 | 2 | 4 | 2 |
| 750 to 7500 | ..... | ..... | 2 | 4 | 6 |
| 7500 to 40 000 | ..... | ..... | ..... | 4 | 6 |
| Trolleys | 4 | 4 | 4 | 4 | 4 |
| Guys, span wires, overhead gr. wires, service loops (*c*) | ..... | 2 | 4 | 4 | 2 |

(*a*) Reduce clearances by 1 foot where cross-over conductors are in cable supported by messenger.

(*b*) Supply loops shall not be carried above conductors of over 7500 volts; nor signal loops above conductors of over 5000 volts. Guys, span wires, and overhead ground wires may be either above or below the conductors by the clearances given.

### 222. Increase in Clearances between Conductors for Spans Exceeding 100 Feet.

Where the sum of the distances from the two nearest supporting structures of the two spans concerned in the crossing to the point of intersection of the two spans exceeds 100 feet, the clearances of Table 3 shall be increased as follows:

For copper conductors in each span, increase at the rate of 1 foot for each 50 feet of the excess over 100 feet.

For aluminum conductors in either or both spans, increase at the rate of 1 foot for each 40 feet of the excess over 100 feet.

**223. Increase in Clearances between Conductors for Voltages above 40 000 Volts.**

Where the voltage of either line concerned in a crossing is over 40 000 volts, the clearances given in the table (and increased if necessary for span lengths over 100 feet by rule 222) shall be increased at the rate of 1 foot for each 10 kilovolts above 40 000 volts.

### 23. CLEARANCES OF CONDUCTORS

(Other than Crossing Clearances)

**230. Separation of Line Conductors of each Voltage Classification.**

The minimum normal separation of conductors, not of the same phase or polarity, when supported by pin type or strain insulators, shall, for spans less than 1000 feet in length, be 1 inch for each 20 feet of span length plus 1 inch for each 1 foot total sag, or fraction thereof, as required by rule 213 for conductor sags.

In no case, however, shall this separation, or the clearance between conductors and the surfaces of supporting structures, or between conductors and span or guy wires attached to the same structure, be less than indicated in Table 4.

**TABLE 4**

**Clearances between Line Conductors of the Same Circuit or of Different Circuits of the Same Voltage**

| Operating voltage | Clearance between conductors | Clearances from span and guy wires | Clearances from surfaces of poles |
|---|---|---|---|
| | Inches | Inches | Inches |
| Signal (a) | 9 (c) | 6 | 3 |
| D. C. Ry. feeders #4/0 or Larger from 0–750 Volts | 8 | 8 | 3 |
| 0–7500 volts (b) | 12 | 8 | 3 |
| Increase per kilovolt above 7500 volts (d) | 0.75 | 1 | 0.25 |

(*a*) Signal conductors may be attached to the under surface of crossarms.

(*b*) Above clearances may be reduced one-half for conductors operating at below 750 volts when carried on racks at the top of the pole or on one side of a pole if the full width of climbing space is maintained past the racks to any conductor or attachment above.

(*c*) Where necessary to provide clearance at points of congestion, this may be reduced to 6 inches.

(*d*) This rule as to spacing is not intended to apply to spans greater than 1000 feet in length or above 40 000 volts. The proper spacing where these limits are exceeded depends not only on the voltage, but upon altitude, length of span, and other conditions which must be considered in each special case.

Clearances from overhead ground wires in the direction of the line should be not less than for conductors of the same class; clearances from lateral and vertical ground wires should be not less than those from pole surfaces.

### 231. Lateral Working Space Between Line Conductors.

A working space between conductors of the same or different voltage classifications not exceeding 20 000 volts, when carried at different levels should be provided by a vertical clearance not less than 24 inches between the two levels, except as noted in rule 230 (*b*). For higher voltages this space will be governed by the arrangement of the conductors and their normal spacing from each other.

This 24 inches indicates the minimum vertical separation between crossarms (center to center) at the pole.

### 232. Vertical Clearances Between Line Conductors of Different Circuits Operating at Different Voltages.

(*a*) The minimum normal vertical clearance between conductors when operating at different voltages and supported by pin type or strain insulators shall be 1 inch for each 20 feet of span length plus 1 inch for each 1 foot of total sag or fraction thereof.

In no case, however, should this clearance be less than indicated in Table 5 at 60° F. with no wind or other mechanical loading of the conductors or wires.

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.

If the conductors of the two lines concerned are carried on different structures, clearance must be not less than that given in the table, and in no case less than 4 feet in any direction. On the same structure conductors of the same voltage classification may be on the same level.

**TABLE 5**

**Vertical Clearances**

In feet between line conductors of different circuits.

| Voltage classification | 0 to 150 volts | 150 to 750 volts | 750 to 7500 volts | 7500 to 40 000 volts | 40 000 volts up |
|---|---|---|---|---|---|
| Signal | 2 | 2 | 4 | 6 | ..... |
| 0 to 150 | ..... | ..... | 2 | 6 | 10 |
| 150 to 750 | ..... | ..... | 2 | 6 | 10 |
| 750 to 7500 | ..... | ..... | ..... | 6 | 10 |
| 7500 to 40 000 | ..... | ..... | ..... | ..... | 10 |

The above specified clearances indicate the minimum vertical separation between crossarms (center to center) at the pole.

For conductors strung with the same sag on all crossarms these clearances would be maintained in the span as well. Where a difference in sag between the conductors on two adjacent crossarms reduces this clearance by more than 25% the sags should be readjusted or the crossarm spacing increased.

### 233. Clearances for Suspension Insulators.

For conductors supported by suspension or disc type insulators, the tabulated minimum clearances of Tables 4 and 5 shall be increased by not less than one-half the distance between the lowest fixed supporting point of the insulator and the conductor, unless the conductor is restrained from undue movement by the use of two strings of insulators properly placed.

### 234. Clearances of Vertical and Lateral Conductors.

(*a*) Climbing Space.—Vertical and lateral conductors, ground wires, and metal sheathed cables shall not obstruct the vertical

climbing space (rule 256) nor the lateral working space between line conductors at different levels (rule 231) nor interfere with the safe use of pole steps where such are installed.

(*b*) Clearances From Pole Center.—Vertical conductors (except where specially protected as per (*d*) below, or where on pole top fixtures) shall not come nearer than 20 inches from the pole center, and if over 7500 volts not nearer than 24 inches.

(*c*) Clearances Between Conductors and From Conductors to Surfaces of Structures.—Vertical and lateral conductors over 7500 volts (except where protected as per (*d*)) shall have clearances from other conductors and from surfaces of structures required in rules 230 and 232 for line conductors.

Such conductors under 7500 volts (except where protected as per (*d*)) shall have at least 3 inches clearance from conductors or surfaces of structures except as indicated in note (*a*) of rule 230.

(*d*) Specially Protected Conductors.—Vertical and lateral conductors over 7500 volts may have less clearances than required by (*b*) and (*c*), if they have suitable insulating covering, and are encased in insulating conduit. Such conductors under 7500 volts may have less clearances than required in (*b*) and (*c*), if having suitable insulating covering and encased in insulating conduit or in other substantial insulating and protective covering. Vertical signal conductors carried within 40 inches above, or 6 inches below supply conductors, and within 20 inches of the pole center, must be similarly protected.

Vertical supply conductors carried within 40 inches from signal conductors shall be encased in insulating conduit or suitable protection (according to the voltage), and if over 7500 volts shall be so protected wherever below signal lines on any structure, except that within 10 feet from the ground the conduit may be metal.

(*e*) Ground Wires and Grounded Metal Sheathed Cables.—Ground wires and grounded metal-sheathed cables shall have clearances from other conductors and from surfaces of structures (unless metal) not less than those required by rule 230 for conductors with which these wires or cables are associated; or where within these clearances shall be inclosed in suitable insulating conduit.

(*f*) CONDUCTORS NOT IN CONDUIT.—Conductors not encased in conduits shall have the same clearances from conduits as from other surfaces of structures.

**235. Clearances from Buildings.**

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

(*b*) Supply conductors of lower voltages (unless in grounded conduit or metal-sheathed cable) shall be so arranged that they do not come nearer than 30 inches, measured horizontally, from 150 to 750 volts and 5 feet up to 7500 volts from any point on the surface of a building or its attachments, and not less than 8 feet above the top of any building crossed over.

Where the above clearances cannot be provided or where conductors come near enough to windows, verandas, fire escapes, or other accessible places to be exposed to contact of persons, the conductors must be properly guarded.

This rule does not prohibit the permanent attachment of open electrical conductors of any class to buildings for means of an entrance, but open conductors should not be carried along or near the surface of a building, unless they are below 750 volts, are guarded or made inaccessible, and have clearances from each other and building surfaces as required by Table 4.

(*c*) Conductors (not in grounded conduit or metal-sheathed cable) operating at over 7500 volts 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 any building not concerned in the operation of the utility owning them.

### 24. GUARDING LIVE AND ARCING PARTS

**240. Switches, Automatic Cutouts, and Lightning Arresters.**

Switches, automatic cutouts, and lightning arresters shall be inclosed when located within 20 inches from the center of a pole, except when located on or above the top cross arm.

**241. Lamps.**

All lamps shall be maintained not less than 20 inches from surfaces of pole structures (unless at pole tops), 15 feet above road-

ways, and 10 feet above footways. When lights over roadways are near the curb, they may be lower if desired.

**242. Insulating or Mechanical Guards for Guy and Span Wires.**

(*a*) Each guy wire or guy strand attached to any pole or structure (except on fenced right of way) to which is attached wires or cables for transmitting electrical energy shall be equipped with an effective insulator at a distance of not less than 8 feet below its point of attachment to such pole or structure (such distance to be measured along the line of the guy) and at a point not less than 8 feet vertically above the ground. Guy wires to poles, carrying lines above 20 000 volts shall be grounded, if carried within 8 feet of the ground.

Where guy wires are exposed to overhead supply wires, insulators shall also be used on guy wires attached to poles carrying only signal lines.

(*b*) All span wires and brackets shall have insulators inserted between them and any trolley contact wire or electric lamp supported by them. In addition, a strain insulator shall be inserted in the span wire supporting a trolley contact conductor or lamp (or in the bracket suspension wire supporting a trolley contact conductor), except for wood poles not carrying conductors of different voltages from the trolley wire or lamp circuit.

(*c*) The ground end of all guy wires or strands attached to ground anchors exposed to traffic shall be provided with a wooden or metal guard at least 2 inches in diameter and 7 feet long.

**243. Trolley Contact Conductors.**

All overhead trolley contact conductors shall be so supported and arranged that the breaking of a single support will not allow the trolley conductor or its current carrying connections to come within 10 feet from the ground or from any platform accessible to the general public.

## 25. SUPPORTING STRUCTURES

**250. Poles or Towers—Clearances and Identification.**

Poles, towers, or other supporting structures for supporting electrical conductors shall be so located, when practicable, as to

provide horizontal clearances from them to the nearest point of railroad tracks, hydrants, and curbs, not less than the following:

| | |
|---|---|
| From hydrants and signal pedestals | 4 feet. |
| From curb lines | 6 inches. |

The spacing between adjacent wood poles in municipalities should generally not exceed 150 feet.

When mechanical loads are to be imposed on poles, towers, or other supporting structures greater than will be safely supported by them alone, additional strength shall be provided by the use of guys, braces, or other suitable construction. Guys are recommended at all unbalanced corners and ends where practicable.

Poles, towers, or other supporting structures on which are maintained electrical conductors shall be identified by a suitable numbering system, and a sufficient number of poles or structures marked as to make it possible to determine the number and ownership of every pole or structure.

**251. Guys and Anchors.**

Guy wires should be stranded and where attached to anchor rods should be protected by suitable guy thimbles. Wooden poles, to which any guy having a strength of 10 000 pounds or over is attached, should be protected by the use of suitable guy shims, and the guys should be supported by guy hooks or other approved means.

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.

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. Crossarms.**

Crossarms shall always be faced on the opposite side of the pole from that on which the maximum stress occurs. On straight lines where the spans between poles are equal the crossarms shall be faced alternately on succeeding poles, first in one direction and then in the other. At crossings they should be attached to the face of the structure away from the crossing, unless special bracing or double crossarms are used.

**253. 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 corrodible material, should be protected by galvanizing or other treatment.

**254. Climbing Space.**

All poles or structures carrying crossarms on which supply wires 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.

When signal conductors are carried above supply conductors, the above climbing space shall extend up to a point at least 40 inches above the highest supply conductors carried on the pole.

The object of this last is to cover the case where signal conductors are carried *above* supply conductors, as in St. Louis.

Where men must climb between live conductors above 750 volts, this climbing space should be increased when practicable to 40 inches; above 20 000 this should be still greater.

Vertical runs encased in suitable conduit or other protective covering (rule 234d) and securely attached to the surface of the pole or structure, or the pole or structure itself when included in one corner of this space at buck or reverse arm construction, are not considered to encroach on the climbing space.

Horizontal runs of cable or wire are not considered to encroach on the climbing space if at least 4 feet above or below all line conductors carried on crossarms, and all such cables or wires shall be protected where within 20 inches from pole center by suitable guard arms or substantial insulating coverings unless at least 6 feet above or below. If uninsulated from metal supports attached to the pole, similar protection shall be provided for such supports for at least 20 inches from the pole center.

All poles should be kept free from posters, bills, tacks, nails, and other unnecessary obstructions.

**255. Branch Connections.**

Connections of branches in supply circuits, service drops, and equipment in overhead construction shall be made at poles or other structures.

**256. Transformers, Regulators, Lightning Arresters, Lamps, Lamp Supports, and Similar Equipment.**

(*a*) Transformers, regulators, and lightning arresters, when located below conductors or other attachments and less than 20

inches from the center of the pole, shall be maintained on that side of the pole opposite to the climbing side, at that point.

(*b*) All exposed live parts of switches or automatic cutouts, lightning arresters, transformer connections, and other equipment, which may require adjustment during operation, shall be spaced not less than 20 inches from pole center and so arranged that in their adjustment, during operation, the hand need not be brought nearer to any other live part at a different voltage than the clearances from pole surfaces required in Table 4 for conductors of corresponding voltages.

### 26. CONDUCTORS AND INSULATORS

**260. Material and Minimum Size.**

No single strand solid drawn conductors of steel, iron, or aluminum wire shall be used as electrical supply conductors in urban districts above any other conductor nor for circuits over 750 volts. It is recommended that no such wires used for signal conductors shall be installed above supply conductors of over 150 volts in urban districts, nor over 750 volts in any place.

All wires shall be of copper, aluminum or copper-covered steel, or other noncorrodible material, and no wire shall be used for supply lines having a breaking strength less than that of No. 8 A. W. G. hard drawn copper. For spans longer than 150 feet, a stronger wire than No. 8 shall be used.

Wires having a breaking strength less than No. 12 A. W. G. hard drawn copper should not be used for signal lines.

Aluminum conductors for all voltages shall be stranded and not less than No. 4 A. W. G.

**261. Tie Wires or fastening.**

Conductors for supply lines, or signal conductors above supply lines, shall be so tied or fastened to insulators as to provide mechanical strength not less than that of the conductor supported, except for conductors of strength greater than 1500 pounds.

Tie wires or fastenings shall have no sharp edges, burrs, or sharp angles at contacts between conductors and ties or fastenings.

**262. Marking Insulators.**

Insulators above 7500 volts operating voltage should be marked by the makers with a classification number, and maker's name or trade mark.

## UNDERGROUND LINES

### 27. MANHOLES, HANDHOLES, AND DUCTS

**270. Location.**

(*a*) Underground systems of electrical conductors should be so located as to be subject to the least practicable amount of disturbance. When being designed and installed care should be exercised to avoid catchment basins, street railway tracks, gas pipes, or other underground structures which have been installed or are planned for the future.

(*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 not less than 25 feet radius, and manholes or other outlets spaced closer together than on straight runs.

**271. Grading.**

Manholes should be so located and ducts so graded that drainage of ducts will always be towards manholes or handholes. To insure satisfactory drainage the ducts should be so installed as to provide a grade of not less than 3 inches in 100 feet of length.

**272. Accessibility.**

Manholes should be so located as to provide safe and ready 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.

**273. Mechanical Details.**

(*a*) The mechanical design and construction of manholes and handholes shall be such as to provide sufficient strength to safely sustain the mechanical loads which will be imposed 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 dimension will be not less than 3 feet 6 inches, and should be so arranged as to maintain a clear working space whose least dimensions are 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. Where conditions will permit, a larger working space than the above should be provided.

(*d*) Manholes and handholes shall be so arranged, if practicable, as to provide permanent drainage through trapped sewer connections or otherwise for such surface or drainage water as may flow into them.

**274. Manhole Covers.**

Manholes and handholes while not being worked in shall be securely closed by covers of sufficient strength to sustain such mechanical loads as will be imposed upon them, and so secured in place that a tool or appliance is required for their opening or removal.

**275. Mechanical Barriers and Guards.**

Manhole openings shall be so arranged that they may, when uncovered, be surrounded by substantial metal barrier guards.

**276. 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 permit the safe installation and maintenance of all conductors or cables to be maintained in them.

**277. Installation of Ducts.**

(*a*) Conduits should, where necessary, be laid on suitable foundations of sufficient mechanical strength to protect them from settling and be protected by covers where necessary to prevent their disturbance by workmen when digging, or by other causes. A sufficient depth shall be provided between the top of the duct covering and pavement surface or other surfaces under which the duct run is constructed.

(*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.

Duct openings into manholes, handholes, or other permanent openings of underground systems shall be provided with an effective bushing.

(*c*) Duct runs should provide as great a clearance from other underground structures as practicable. 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.

(*d*) Joints in duct runs shall be made reasonably water-tight and mechanically secure to maintain individual ducts in alignment.

(*e*) No duct should enter any manhole, handhole, or other permanent opening of underground systems of distribution at a distance of less than 6 inches above the floor line or below the roof line.

(*f*) Ducts of laterals supplying service to buildings should be effectively plugged or cemented by the use of asphaltum, pitch, or other suitable means to prevent gas entering the consumers' premises through the ducts.

### 28. CONDUCTORS AND EQUIPMENT

**280. Location and Identification of Conductors.**

(*a*) Underground systems of electrical supply and signal conductors for public use shall be maintained in separate conduits and manholes.

(*b*) Cables shall be permanently identified, by tags or otherwise, at each manhole, handhole, or other permanent opening of the underground system.

(*c*) Cables in manholes shall be readily and safely accessible from the clear working space at all times. When such cables cross by or over other cables sufficient clearance shall be provided between cables.

Joints made in or branches made from underground cables shall be readily accessible at all times and shall be in manholes or handholes, and as seldom as possible within the ducts themselves.

(*d*) Each cable, where practicable, shall maintain a vertical clearance above the floor of any manhole of not less than 6 inches.

**281. Mechanical Protection and Support.**

(*a*) Cables shall be provided with a continuous water-tight metal sheath or other waterproof covering over their insulating coverings.

(*b*) Protective, control, or other apparatus installed and maintained in manholes and handholes shall be enclosed in water-tight metal 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. Individual supply cables not laid on separate shelves of fire-resistive material should be provided with suitable insulating mechanical coverings to protect them from arcs caused by neighboring conductors or cables.

A substantial covering of cement and sand mortar over a sisal rope wrapping is highly recommended for this purpose.

(*d*) Conductors or cables from underground systems which connect to overhead systems shall be mechanically protected by installing in grounded metal conduit and shall terminate in approved potheads or similar devices of approved design or construction; the open wiring above shall begin not less than 10 feet above the ground surface or any accessible platform.

(*e*) Joints or terminals of conductors or cables of underground systems of electrical distribution shall be so arranged that there are no bare ungrounded current-carrying metal parts exposed to accidental contact.

**282. Spacing.**

(*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*) Conductors or cables belonging to low voltage direct current or secondary distribution circuits not exceeding 750 volts shall not be installed or maintained in the same duct with cables of other systems of higher voltages or with railway circuits under 750 volts. Conductors or cables of systems operating at voltages in

excess of 750 volts may be installed and maintained in the same duct at the discretion of the operating company.

**283. Electrical Protection of Building Services.**

Service conductors from supply systems shall enter a building only through a tight metal case containing an approved automatic cutout and switch so arranged that no service conductor is exposed to mechanical injury within the building.

When installed in circuits operating at above 750 volts, the above specified switch should provide a positive air gap when disconnected. If not, a disconnector shall be installed which will provide such air gap.

**284. Multiple Connections.**

When transformers, regulators, or other similar apparatus operate in multiple, tags or other suitable means shall be used to indicate that fact.

Multiple operation of transformers, regulators, or other similar apparatus shall not be permitted between equipment maintained in overhead construction and that maintained in underground construction.

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# PART 3.—RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRICAL UTILIZATION EQUIPMENT.

CONTENTS.

## SCOPE OF THE RULES

The following rules apply to electrical utilization equipment under 750 volts, and accessible to other than specially qualified operators, as in factories, mercantile establishments, and similar places.

Generating and other equipment, if enclosed in a separate room inaccessible to unauthorized persons, and under control of a qualified operator, shall comply with the rules for stations.

Equipment and conductors over 750 volts, not so enclosed, but in rooms to which others than properly qualified electrical operators have access, shall, in addition to complying with the rules for stations and such of the following rules as apply, have all live parts either encased in permanently grounded metal cases or conduits, or otherwise suitably guarded to prevent access or unsafe approach by any but specially authorized persons to such live parts.

The rules apply fully to all new installations except as modified by the proper administrative authority. They apply to existing installations, (*a*) in extensions and reconstructions, except where for special reasons this is impracticable; (*b*) in cases of serious danger that can be obviated by conforming to the rules; (*c*) in the placing of guards and grounding of parts where the expense is not substantially greater than would be required for providing such protection for new equipment.

The time allowed for compliance with (*b*) and (*c*) will be fixed by state or municipal administrative authorities.

### 30. PROTECTIVE ARRANGEMENTS

**300. General Requirement.**

(*a*) All electrical utilization equipment shall be of suitable design and construction and adequate for the work to be performed, and so installed and maintained as to reduce the life hazard as far as practicable.

(*b*) It is recommended that equipment comply when new with the standardization rules of the American Institute of Electrical Engineers.

**301. Inspection.**

Electrical utilization equipment with its associated guards and appliances shall not be placed in use until found to comply with these safety rules, and shall thereafter be systematically inspected and cleaned and defects recorded. Defective equipment shall be put in good order or permanently disconnected. Defective wiring shall be removed.

**302. Grounding.**

(*a*) GROUNDING METHOD.—All lightning arrester grounding, and the grounding of all equipment, wire runways, and circuits, when this grounding is intended to be a permanent protective measure, shall be made permanent and effective, and so arranged that under normal conditions there is no appreciable passage of current over the ground connection.

To secure permanent and effective grounding, the grounding methods specified in Appendix A, or other equivalent means should be employed.

(*b*) WHAT CIRCUITS MUST BE GROUNDED.—In addition to the circuits, grounding of which is required by the following rules, all circuits installed in rooms or spaces to which other than properly qualified electrical workmen have access shall be permanently grounded in accordance with the rules of Appendix A, except as follows:

(1) 2-wire direct current circuits.

(2) Circuits entirely unexposed either through overhead construction or through transformers or other devices to leakage or induction from other circuits. It is recommended, however, that all 3-wire (not 3-phase) circuits, even if unexposed, be grounded at the neutral point.

(3) Circuits over 150 volts in which all live parts of conductors and equipment are incased throughout in permanently grounded metal conduit or cases.

(*c*) GROUNDING NONCURRENT CARRYING METAL PARTS.—All exposed noncurrent carrying metal parts of fixed electrical utilization equipment (such as frames of motors and switchboards and cases of transformers, switches, and devices) shall be permanently grounded, (1) if operating at over 150 volts to ground, or (2) if in hazardous locations. (For portable devices see section 37).

Hazardous locations include those where dampness, explosives, inflammable gas, or flyings exist. They also include those where exposed grounded surfaces (such as metal frames of other machines, plumbing fixtures, concrete or earth floors or walls) exist within reach of persons while touching the metal parts under consideration. Usually, grounded surfaces within 3 feet horizontally from the parts considered and within 8 feet vertically from floor are within reach.

EXCEPTION—SINGLE-VOLTAGE SWITCHBOARDS.—No ground connection need be made to exposed metal frames of switchboards on which all current carrying parts operate at the same potential not exceeding 750 volts to ground (such as trolley switchboards in car

barns); provided that such frames are effectively insulated from the ground and the switchboards are surrounded to an adequate distance by suitable insulating floors or platforms, and are accessible only to properly qualified and authorized persons.

**303. Working Space About Electrical Equipment.**

Adequate working space, with secure footing, shall be provided and maintained about all electrical utilization equipment which must be approached or which requires adjustment, examination, or similar attention during operation. Moving parts in these spaces shall be provided with approved barrier guards.

The spaces shall be so arranged as to give the authorized attendants ready and safe access to all parts requiring attention, and unless live parts are suitably barriered shall provide the following minimum working spaces:

If there are exposed live parts on one side, the minimum width shall be 2½ feet; if on both sides 4 feet.

**304. Guarding or Isolating Live Parts.**

(*a*) All ungrounded current carrying parts of electrical utilization equipment (such as terminals of controllers and motors, bus bars, and other conductors) operating at over 150 volts to ground and not isolated by elevation at least 8 feet above floor line, should be provided with approved permanent inclosures or other guards so arranged as to prevent persons or conducting objects from inadvertently coming (or being brought) in contact with them.

(*b*) Where current carrying parts at over 150 volts to ground are necessarily exposed within 8 feet from floor line, all surrounding conducting floors and similar surfaces within reach shall be covered with suitable insulating platforms or mats.

The suitable guarding 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.

(*c*) Trolley or crane collector wires and third rails, not effectively isolated by elevation, shall be provided with guards so arranged that persons can not inadvertently touch the current-carrying parts while in contact with the ground, conducting platforms, or other conducting surfaces.

Concrete floors and damp wood are conducting surfaces, and metal parts of crane cabs are grounded.

**305. In Hazardous Locations.**

Regardless of voltage all current carrying parts of electrical utilization equipment, located where dampness, explosives, or inflammable gas, or flyings exist, shall be inclosed in suitable casings. The latter shall be nonabsorptive, noncombustible, and when of metal, shall be permanently grounded. Where inflammable gas exists, casings inclosing parts at which sparking or arcing can occur shall be made explosion proof.

**306. Storage Batteries, Transformers, and Lightning Arresters.**

The installation of such apparatus shall comply with the requirements given in sections 13, 14, 18 of the rules for Stations, except as noted in paragraphs (*a*) and (*b*) below.

(*a*) Where storage batteries are placed in rooms occupied by other equipment, adequate guards or inclosures shall be provided when necessary to prevent the approach of unauthorized persons. Above 50-kwh., or 150 volts, all batteries shall be placed in separate rooms and shall conform with the requirements of section 13.

(*b*) At least one suitable lightning arrester shall be provided on each ungrounded conductor connecting utilization equipment with overhead lines where such lines extend over 1000 feet in locations where lightning occurs. Such arresters shall be isolated or guarded so as to be inaccessible to all but authorized persons.

**307. Identification.**

All electrical utilization equipment and circuits shall be adequately identified by position, color, number, name plate, label, or design, as to voltage, intended use, and proper connections.

All connections shall be arranged in a simple and orderly manner.

## 31. CONDUCTORS

**310. Protection in General.**

(*a*) ARRANGEMENT.—Conductors shall be suitable for the location, use, and voltage, and shall, except grounded conductors and ground wires, be protected against excessive current by the design of the system, or by automatic cutouts.

Neutral conductors in 3-wire systems and all grounded conductors between the source of electrical supply and the point to which the ground wire is attached shall be arranged without automatic cutouts interrupting their continuity and without

manual switches, unless the switch opens all conductors of the circuit at once.

Conductors of circuits supplied from one or more sources of electrical energy shall be provided with suitable switches to safely disconnect them from all such sources.

(*b*) MECHANICAL AND THERMAL PROTECTION.—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 rigidly supported or shall be in approved conduit or substantial noncombustible, nonabsorptive casings.

Where exposed in open construction to danger of arcing of other conductors, or to any combustible material, suitable and substantial noncombustible outer covering shall be employed for insulated conductors.

Bare conductors shall be used ungrounded only for switchboard and storage battery connections, and for trolley wires and other contact conductors.

**311. Isolating or Inclosing.**

REQUIREMENT.—All fixed conductors over 150 volts to ground, and bare and ungrounded conductors at all voltages shall (unless guarded as required in rule 312) be so isolated by elevation (as required by rule 304 (*a*)), that no person can inadvertently come in contact with them.

**312. Guarding Conductors Over 150 Volts.**

(*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. In damp places conduit must be made waterproof and provided with suitable means of draining off condensation.

(*b*) OPEN CONDUCTORS BELOW 750 VOLTS.—Where open insulated conductors between 150 and 750 volts to ground, or any open bare conductor at any voltage below 750 volts, is necessarily brought closer to floor line than 8 feet, they shall be guarded by permanent screens or inclosures. Where persons at any time

pass by or remove screens or other guards while conductors are alive, 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.

**313. Guarding in Hazardous Locations.**

(*a*) Conductors in locations where inflammable gas 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.

(*b*) Conductors in damp locations, if not in conduit, or in waterproof metal sheaths in other suitable ducts, shall be effectively isolated and supported on suitable type insulators.

**314. Portables and Pendants.**

Portable or pendant conductors shall not be installed or used on circuits operating at over 150 volts to ground, unless they are of special type suited to the voltage and conditions, and conform to the rules of section 37.

**315. Temporary Wiring.**

No wiring shall be installed for temporary use which is not in compliance with these rules, unless it is under constant supervision of a properly qualified person, while it or neighboring wiring is alive.

**316. Taping Bare Ends and Joints.**

Bare ends and joints of insulated conductors shall have equal insulating covering with other portions of the conductor. This applies to temporary as well as to permanent construction. Such parts of conductors shall be installed only where supported on insulators; or located in junction boxes, outlet boxes, or similar points in conduits or other casings.

**317. Guarding Service Conduit.**

(*a*) Isolating or Grounding.—Metal conduit or sheathing incasing service conductors from either overhead or underground lines shall either be permanently grounded or so isolated by elevation (see rule 304), or so guarded that no person can come in contact with the conduit or sheathing.

(*b*) INSULATION BETWEEN SERVICE CONDUIT AND INTERIOR CONDUIT.—Metal conduit or sheathing incasing service conductors from supply lines to service cutout shall be so arranged that a suitable nonabsorptive, noncombustible dielectric is interposed between such outside conduit or sheathing and any such metal covering of conductors within the building or any metal work of the building itself, unless the metal covering of outside conductors is separately grounded to water pipe through a ground wire not smaller than No. 6.

### 32. SWITCHES, FUSES, AND OTHER CUTOUTS, CONTROLLERS AND OTHER CONTROL DEVICES

**320. Accessible and Indicating.**

All switches, automatic cutouts, controllers, starting rheostats, and other control devices shall be readily and safely accessible to authorized persons; shall be so located or marked as plainly to indicate 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 and so that gravity can not close them.

**321. Hazardous Locations.**

When necessary to install switches or other control devices in locations where explosives, inflammable gas, or flyings exist they shall be incased in explosion-proof permanently grounded cases.

**322. Where Switches are Required.**

(*a*) Suitable switches shall be inserted in all circuit leads (except a grounded conductor) to motors, transformers, storage batteries, electric furnaces, and other utilization equipment. Except with potential transformers, small lighting circuits, and similar uses, these switches shall interrupt all leads of the circuit (except a grounded conductor) at a single operation.

(*b*) Suitable means shall be provided (such as switches with locks or blocks and tags) so that all electrical equipment can be prevented from being made alive and from starting, when persons are working on or about them, unless all live and moving parts are so guarded as to render this unnecessary.

**323. Character of Switches.**

(*a*) CAPACITY.—Switches other than disconnectors shall be able to interrupt safely the largest currents to which the switch is limited by the design of the system or by automatic cutouts in circuit.

Where used only as disconnectors to interrupt only unloaded circuits, or to interrupt only a limited part of the load which they may be at times called upon to carry, switches shall be plainly marked with warning against opening while carrying current in excess of the safe limit.

Interlocking arrangements are desirable to prevent opening of such switches under loads beyond their capacity.

(*b*) LOCKING.—Means shall be provided so that switches can be locked or blocked in the open position and tagged to prevent careless closing while work is being done on equipment controlled by them.

Small capacity snap switches, if near machine and in plain sight from all parts of the machine controlled, are exempted. Locking is recommended rather than blocking, wherever parts of the machinery driven are remote from the point of control.

(*c*) ALIGNMENT.—Switches shall maintain such alignment under service conditions that they may be closed with a single unhesitating motion.

**324. Disconnection of Fuses Before Handling.**

(*a*) AUTOMATIC DISCONNECTION.—Fusible cutouts in circuits operating at over 150 volts to ground, or in circuits not limited by other automatic cutouts to 30 amperes or less, shall be so arranged that their live parts can not be touched by persons refusing the cutouts until the latter have been disconnected from all sources of electrical energy.

(*b*) NONAUTOMATIC DISCONNECTION.—Where fusible cutouts are in locked cabinets or otherwise made inaccessible to all but qualified persons, sufficient protection is usually secured by the use of a switch accessible only to such person, this switch to be placed between the fuse and the supply.

**325. Arcing or Suddenly Moving Parts.**

(*a*) SHIELDING FROM ARCS.—Fuses and circuit breakers shall, as far as possible, be so located and shielded that persons can not be burned.

(*b*) Parts which may move suddenly, such as handles or levers of circuit breakers, shall be so guarded or isolated that persons in the vicinity can not be struck.

**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 302.

**327. Guarding Live Parts of Switches and Automatic Cutouts.**

(*a*) All manual switches shall have suitable casings, safely protecting the operator from danger of contact with current-carrying parts, or shall be provided with insulating handles, and an insulating guard disc or shield so arranged between the handle and the live parts as to prevent the hand from slipping into contact with live parts or being burned by arcing at the switch.

Switches under 150 volts to ground and limited to 30 amperes by automatic cutouts in series may be excepted from the above requirement.

(*b*) Where live parts of switches or automatic cutouts operating at over 150 volts to ground are not provided with inclosing guards, effective during ordinary operation or adjustment, suitable insulating floors, mats or platforms, shall be provided on which the operator may stand while operating the switches or adjusting automatic cutouts, and any conducting walls or machine frames within 3 feet shall be provided with suitable insulating guards. Such switches or automatic cutouts shall be made inaccessible to other than properly qualified persons by inclosure in locked cabinets or rooms.

### 33. SWITCHBOARDS

**330. Accessibility and Convenient Control.**

Switchboards shall have all switches so arranged that the points of control are quickly and safely accessible to the operator.

**331. Convenient and Safe Attendance.**

Switchboards shall have all instruments, relays, or other devices requiring reading or attention so placed that work can be readily performed without unsafe approach to any live parts.

**332. Safe Location.**

Switchboards shall be so located that the persons necessarily near the board can not be endangered by machinery or equipment located near the board.

**333. Arrangement and Identification.**

Connections, wiring, and equipment of switchboards shall be arranged in an orderly manner and all switches and other cutouts shall be plainly marked or labeled to identify the circuits or equipment supplied through them.

Switchboards shall have live parts which are ordinarily isolated or guarded, but which may occasionally require adjustment or repair during operation, so arranged that suitable portable covers or shields can be effectively secured about them to guard against all neighboring live parts.

It is recommended that a diagram of switchboard connections and devices be kept posted in some convenient place near such equipment.

**334. Illumination.**

Permanent means of illumination shall be provided for the entire switchboard so that adjustments may be safely performed, and instruments clearly read.

**335. Spacings and Barriers Against Short Circuit.**

Switchboards shall have bare parts at different voltages on any panel reduced to a minimum; and these parts shall be effectively separated.

Such parts, including bus bars, should, when practicable, be so located or provided with barriers that parts of different potential will not be accidentally short circuited by tools or other conducting objects.

**336. Grounding Frames.**

Switchboard frames should be permanently grounded, under the conditions noted in rule 302.

**337. Guarding Live Parts.**

(*a*) All switchboards and panel boards having exposed current-carrying parts operating at over 150 volts to ground and not isolated by elevation shall be suitably inclosed in locked cabinets or rooms to make them inaccessible to others than the authorized

operator. They shall also have a suitable insulating floor, platform or mat so arranged that no person can inadvertently touch such a part unless standing on the insulating floor, platform or mat.

(*b*) Plug type switchboards shall have no current carrying parts exposed on face of boards, and plug connectors should have all current carrying parts guarded.

### 34. MOTORS AND MOTOR-DRIVEN DEVICES

**340. Control Devices.**

(*a*) Separately excited motors, motor generators, and converters where it is possible for them to be driven from the d. c. end by a reversal of current, shall be provided with speed limiting devices.

(*b*) Where the speed control of direct-current motors is accomplished by varying the field resistance, the field rheostats shall be so arranged with no-voltage release or other devices that the motor can not be started under dangerously weakened field.

Starting rheostats for d. c. motors shall be arranged with no-voltage release, actuated on failure of the field circuit.

(*c*) Where speed limiting and stopping devices are electrically operated, the control circuits by which such devices are actuated shall be in conduit.

**341. Hazardous Locations.**

Motors in which sparking can occur during operation shall have explosion proof inclosing cases, when in locations where inflammable gas or flyings or explosives are present. Where practicable, motors shall be kept out of such locations.

**342. Deteriorating Agencies.**

Suitable guards or inclosures shall be provided to protect the current carrying parts, insulation, and leads of motors where installed directly under equipment or in other locations where dripping oil, excessive moisture, steam, vapors, or other similar injurious agents exist.

**343. 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 150 volts to ground, that operators can not touch such parts unless standing on the mats or platforms.

The suitable guarding 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 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.

(*b*) Where machines are mechanically coupled together, and the operator can touch the frames of more than one at a time, the frames of all shall be grounded unless they are bonded together electrically, and surrounded by insulating mats or platforms.

**344. Grounding for Noncurrent Carrying Parts.**

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 302, and with the exceptions therein provided.

**345. Protecting Moving Parts.**

Suitable guards or inclosures shall be so arranged at each motor or motor-driven device as to prevent persons or objects from inadvertently coming in harmful contact with moving parts.

### 35. ARC WELDERS AND ELECTRIC FURNACES

**350. Arc Furnaces.**

Electric furnaces, such as those used for arc welding, where intensely glowing or incandescent arcing parts are exposed, shall be inclosed, so that those parts will not be accessible or visible to unauthorized persons. Suitable protecting hoods, gloves, and other devices shall be provided for the authorized operators or others who must work or come near such parts.

**351. Grounding.**

The outside noncurrent carrying metallic frame of furnaces which contain live parts shall be grounded.

Where the heating element is a low voltage secondary or part of a low voltage circuit, it should be permanently grounded if the operator must bring tools or conducting materials in contact with the element.

**352. Guarding Live Parts.**

Except at points where necessarily left exposed, all current carrying parts shall be suitably guarded in permanently grounded metal inclosures or substantial insulating material. All parts above 150 volts should be so guarded.

## 36. LIGHTING FIXTURES AND SIGNS

**360. Grounding.**

The exposed noncurrent carrying metal parts of all electric lighting fixtures and other fixed electrical devices shall be permanently grounded when used under the following circumstances: (*a*) When the devices are located where dampness, inflammable gas, or explosives exist, as in bath rooms, laundries, gas works, etc.; (*b*) when within seven feet from earth, brick, concrete, or permanently damp floors or walls, as in stables, basements, etc.; (*c*) when within 6 feet from exposed metal piping, metal flues, radiators, stoves, furnaces, plumbing fixtures, gas fixtures, or similar conducting surfaces, as in kitchens, machine shops, print shops, etc.

**361. Insulation.**

Fixtures in the locations specified in the foregoing rule, and all fixtures operating at over 150 volts to ground, shall have a substantial, nonabsorptive, solid dielectric between all underground current carrying parts and parts of the fixture with which a person can come in contact. The dielectric shall under service contions withstand for one minute the application of a voltage test not less than four times that for which the fixture is rated, and at least 2000 volts.

Fixtures exposed to mechanical injury shall have the dielectric protected by an outer metal shell.

**362. Exposed Conductors and Live Parts.**

(*a*) Electric fixtures shall be so designed and installed that no current carrying parts (including lamp sockets and lamp bases, plugs, receptacles, etc.) will be exposed during normal use.

(*b*) It is recommended that the screw shells of sockets and receptacles where used on grounded circuits shall be connected to the grounded conductor.

**363. Accessibility and Guarding of Signs.**

(*a*) Electric signs above roadways or footways at an elevation greater than 30 feet, or above roofs and at an elevation greater than 10 feet above such roofs shall be provided with substantial, safely accessible runways, ladders or platforms from which all necessary adjustments can be made. Provision for supporting workmen by safety belts should be made in the construction and installation of the signs so located.

(*b*) Electric signs outside buildings shall have no current carrying parts normally exposed to contact of workmen.

This requires that receptacles be extended so that the screw base of the lamp or plug can not be exposed when alive.

**364. Control of Outdoor Signs.**

Electric signs shall be provided with switches located within sight of the sign and arranged to entirely disconnect all feed wires of the sign, or with such a switch arranged so that it can be locked in the open position.

**365. Connectors for Signs.**

Electric signs shall be so arranged that changeable connections can be made 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.

**366. Isolating or Guarding Lamps in Series Circuits.**

Arc lamps and other devices in series circuits shall be effectively isolated or suitably guarded.

Isolation will ordinarily be deemed sufficient when a clearance vertically from floors or other ordinarily accessible places within buildings of 8 feet, from footways outside buildings of 10 feet, and for roadways of 15 feet. Clearance horizontally from spaces accessible to the general public should be not less than 3 feet.

Lamps shall be secured from falling on persons or traffic passing below, and the rope, chain, or other means adopted for holding the lamps shall be systematically inspected.

**367. Safe Access to Arc Lamps.**

A suitable device shall be provided, by which each arc lamp or other apparatus may be safely and entirely disconnected from the circuit before it is handled.

When lamps and other devices are to be worked on while alive, suitable means shall be provided by which they may be safely disconnected from the circuit before it is handled, unless stools, platforms, or tower wagons used will provide sufficient insulation for the voltages to be handled.

**368. Bridging Devices.**

The devices used for connecting lamps into series circuits shall provide means of bridging the lamp before the lamp can be removed.

### 37. PORTABLE DEVICES, CABLES, AND CONNECTORS

**370. Insulation.**

Portable devices shall be provided with a substantial, nonabsorptive, solid dielectric interposed between current carrying parts and other conducting parts which persons can touch. This dielectric must be such that under service conditions it will withstand a test of not less than four times the voltage for which the device is rated, but not less than 2000 volts.

Devices in which the insulation is exposed to mechanical injury shall be protected by an outer metal shell.

**371. Grounding.**

The exposed noncurrent carrying frames of portable devices shall be effectively grounded, if the devices operate at over 150 volts and are so installed that they can be carried within four feet of exposed metal surfaces, such as piping, flues, radiators, stoves, furnaces, water fixtures, or damp floors or walls, concrete, brick, or similar conducting and usually grounded surfaces.

The ground connection may be secured by means of an identified grounding conductor in the portable cable, using a polarized connector, or by other convenient means.

Where the operating voltage is under 150, grounding should be secured, if practicable.

**372. Cable Connectors.**

Connectors should be so designed as to be noninterchangeable for connectors of different voltage and current classification.

Where used with portable conductors, connectors must disconnect with one operation all poles from the live source of energy.

Connectors shall be marked for the current and voltage for which they are to be used, and shall be so constructed with guards

that the person using them can not inadvertently come in contact with live parts or be burned by the arcing from the largest current for which they are approved.

Where the two ends of a separable connector are both connected to live circuits, as in battery charging, both ends shall have live parts suitably guarded.

Where attached to portable cables, suitable means shall be provided for relieving the terminal connections of cable from strains.

**373. Identified Conductors and Connectors.**

Where used with portable devices, the cases of which must be grounded, the portable cable and the separable connectors (both to the device and to the circuit) shall be provided with identified parts so that the ground wire in both fixed wiring and portable cable will always be attached to the proper terminals of the connectors. Separable connectors shall be so constructed that wrong connection between the two parts is impossible.

**374. Use of Portables and Pendants.**

Portable and pendant conductors should not be installed or used on circuits operating at over 150 volts, unless they are of special type suited to the voltage and conditions.

> In car houses and similar locations where service at low voltage is not available, it may be necessary to use them, but they should be used only with great precaution and preferably used on the grounded side of such circuits.

Where portable conductors are required, fixed connectors shall be provided at safely accessible points, so located that liability of such conductors being brought into dangerous proximity with other live parts will be reduced as far as practicable.

Portable conductors shall be attached to fixed wiring only through separable attachment plugs which will disconnect at all poles by one operation.

Where exposed to dampness or corrosive influences, portable conductors shall be of a type specially suited; and where exposed to inflammable gas they shall be so 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 and

pendant conductors shall be so installed that no strain is placed on the terminal connections.

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.

### 38. ELECTRICALLY OPERATED CARS, CRANES, AND ELEVATORS

#### 380. Guarding Live and Moving Parts—General Requirement.

All current carrying parts above 150 volts shall be so isolated or guarded that no person can inadvertently come in contact with them.

(*a*) CONDUCTORS.—All conductors shall be guarded against contact by the public, by being run (where otherwise exposed to contact) in permanently grounded metal conduit, armored cable, or metal moldings.

(*b*) EQUIPMENT.—Guards for the current carrying parts of unisolated electrical equipment, including controllers, motors, transformers, automatic cutouts, circuit breakers, switches, and other devices, shall consist of casings of permanently grounded metal or of substantial noncombustible, insulating material.

(*c*) ADJUSTABLE, ARCING, OR MOVING PARTS.—All parts of electrical equipment 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.

All exposed noncurrent carrying metal parts of electrical equipment at over 150 volts to ground shall be permanently grounded.

#### 382. Control of Energy Supply.

Readily accessible means shall be provided whereby all conductors and equipment can be disconnected entirely from the source of energy at a point as near as possible to the trolley or other current collectors.

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.

**383. Control of Movement.**

Means shall be provided whereby the operator (whether motorman or elevator attendant) can prevent starting the equipment by unauthorized persons while absent from his post.

Removable reverse levers and locked doors to the operator's cab, are among the most effective means.

## 39. TELEPHONES AND OTHER SIGNAL APPARATUS ON CIRCUITS EXPOSED AT ANY POINT BY SUPPLY LINES

**390. Grounding Noncurrent Carrying Parts.**

All telephone or other signalling equipment located outdoors or in damp or corrosive locations shall be so arranged that all exposed noncurrent carrying metal parts are permanently grounded.

**391. Guards.**

All telephone or other signalling equipment located outdoors or in damp or corrosive locations shall be so arranged that all current-carrying parts are effectively guarded. Portable cords shall be guarded by nonabsorptive shields, either of permanently grounded metal or of suitable insulating material.

**392. Insulating Booths.**

All telephone or other signalling equipment connected in the same circuit with overhead signal lines paralleling power lines operating at over 5000 volts under any of the conditions noted in the table below, shall be located in booths of suitable insulating material, and so arranged that no person can come in contact with telephone or other signalling equipment unless within such booth.

| Voltages | Spacing of the parallel in feet | Length of the parallel in miles |
|---|---|---|
| 5000 to 27 000 | Less than 6 | Any distance |
| | 6–10 | $\frac{1}{4}$ or more |
| | 10–20 | $\frac{1}{2}$ or more |
| 27 000 to 47 000 | Less than 10 | Any distance |
| | 10–20 | $\frac{1}{4}$ or more |
| | 20–30 | $\frac{1}{2}$ or more |
| 47 000 up | Less than 20 | Any distance |
| | 20–25 | $\frac{1}{4}$ or more |
| | 25–30 | $\frac{1}{2}$ or more |
| | 30–50 | 1 or more |

## APPENDIX A

## GROUNDING CIRCUITS, EQUIPMENT, AND LIGHTNING ARRESTERS FOR STATIONS, LINES, AND UTILIZATION EQUIPMENT

**0. General Requirement.**

All lightning arrester grounding, and all grounding of circuits, equipment, or wire runways, when the grounding is intended to be a permanent protective measure, shall be made permanent and effective and shall be so arranged that under normal conditions there is no appreciable passage of current over the ground connection.

To secure permanent and effective grounding, the following grounding method or other equivalent means shall be used:

**1. Where Ground Wire shall be Attached.**

(*a*) DIRECT CURRENT 3-WIRE SYSTEMS.—The neutral wire in direct current 3-wire systems shall be grounded at the station.

(*b*) ALTERNATING CURRENT SECONDARY SYSTEMS.—The neutral wire of a 3-wire (not 3-phase) secondary, or one side of a 2-wire secondary, of power or instrument transformers, shall be grounded at the transformer, at the service to a building, or (if serving more than one building) at the individual service to each building.

> The ground at the individual building service is recommended where more than one building is served by the secondary system, because of the multiplicity of grounds, their ready accessibility for inspection, and their freedom from liability of corrosion or mechanical damage.

Where transformers feed systems extending over 500 feet, the grounded neutral or the grounded side of the secondary circuit shall be grounded at least every 500 feet.

(*c*) EQUIPMENT.—The point at which the ground wire connection is made to the equipment shall be accessible.

(*d*) LIGHTNING ARRESTERS.—The ground wire shall lead from the ground terminal of the arrester to the ground connection in as direct a line as possible, avoiding sharp bends.

**2. Ground Wire.**

(*a*) MATERIAL AND CONTINUITY.—The ground wire should be of copper, and must be continuous and without joints if practicable.

Approved metal conduit, when necessarily used in place of any portion of the ground wire for equipment or circuits, or for grounding other portions of a conduit system, shall have all joints so made and maintained as to withstand the same resistance and current carrying capacity tests as are required for the ground wire itself by rule 4.

No automatic cutout shall be inserted in the ground connection; no switch shall be so inserted, except in plain sight and effectively isolated from uninstructed persons.

(*b*) SIZE.—For grounding circuits, the cross-sectional area of the ground wire (if copper) shall be not less than one-fourth that of the largest conductor or the total of all conductors utilizing it, and in no case less than No. 6. If other material than copper is necessarily used, the same conductance shall be secured.

For electrical equipment, the current carrying capacities of the ground wires shall not be less than those of the wire sizes given in the following table opposite the ratings of the nearest automatic cutouts through which the grounded equipment is connected to the source of energy supply.

| Required size ground wire A. W. G. | | Capacity of automatic cutouts Amperes |
|---|---|---|
| 18 | Permitted only in portable cord to portable equipment. | 10 |
| 10 | | 10–100 |
| 6 | | 100–200 |
| 0 | | 200–500 |

(*c*) MECHANICAL PROTECTION.—Where exposed to mechanical injury the ground wire shall be protected by substantial conduit or other guard which, if of metal, shall be permanently and effectively grounded, and if for lightning arresters shall be nonmagnetic. On poles or against buildings accessible to other than properly qualified electrical workmen, this protection shall extend from a point below the surface of the ground or platform to a point at least 10 feet above. On side walls inside buildings, unless isolated from all traffic, this protection shall extend from a point below the surface of the ground or platform to a point at least 7 feet above.

(*d*) UNDERGROUND.—Ground wires laid underground shall, unless otherwise mechanically protected, be laid slack to prevent their being readily broken. Joints in underground connections should be avoided (especially between dissimilar metals) and where necessarily used shall be protected against corrosion by thoroughly covering them when dry with waterproof coating and mechanically protecting this coating.

**3. Ground Connections.**

The ground connection shall be permanent and effective and include:

(*a*) PIPING SYSTEMS.—For circuits, equipment, and arresters at supply stations all available underground continuous metallic piping systems and at other places to at least one such system.

Available in this rule means ordinarily within 800 feet for stations or lines and at least 100 feet for utilization equipment.

(*b*) FRAMES OF BUILDINGS.—Where underground metallic piping systems are not available, other approved methods which will secure requisite permanence and conductance may be permitted; as, for example, in some cases the steel frame of a building.

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

1. Three separate grounds should usually be made, unless a smaller number give less resistance than specified in rule 4.

2. If, however, no part of the circuit or equipment protected can be reached by persons standing on ground or damp floors, or by persons touching also any metallic piping to which the ground wire is not effectively connected—a single artificial ground—even if resistance exceeds that specified in rule 4.

3. Arrester grounds may usually be single if the arrester is of small capacity.

(*d*) METHOD.—Ground connection to metallic piping systems should be made outside of main cocks, meters, or other devices which interrupt the continuity of the underground metallic pipe systems, but may be made immediately inside building walls to secure accessibility for inspection and test. If meters, main cocks, or other devices are located outside buildings, they shall be suitably shunted, if the ground connection is made inside the building.

The ground connection to underground 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 wire into a brass plug and screwing the plug tightly into the pipe fitting, or where the pipes are cast iron, into a hole tapped into 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 recorded.

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

Artificial grounds should be spaced not less than 6 feet apart, and be located below permanent moisture level or at least 10 feet deep, where possible, each presenting at least 2 square feet surface to exterior soil. Areas where ground water level is close to the surface should be used when available.

**4. Ground Resistance.**

(*a*) LIMITS.—The total resistance of the ground wires and connections of any grounded circuit or equipment should not exceed the values given below.

| Ohms. | Amperes. |
|---|---|
| 5.0 | 10 |
| 2.0 | 25 |
| 1.0 | 50 |
| 0.5 | 100 |
| 0.25 | 200 |
| 0.1 | 500 |

The product of the corresponding number in the two columns always equals 50.

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

In exceptionally dry soils it may be impossible to obtain as low resistances as specified above, even with 3 grounds in parallel as specified in rule 3 (*c*).

(*b*) CHECKING.—The resistance of any ground wire and its ground connection should be periodically checked by measuring the voltage between the ground wire of the circuit, the frame of the equipment, or the grounded point of the lightning arrester, and any exposed metallic piping in neighboring buildings or vicinity, and if possible while the rated current, according to the above table, is flowing through the ground wire and connections.

**5. Joint Use of Grounds and Ground Wires for Different Systems.**

(*a*) GROUND WIRES.—Ground wires for circuits or equipments shall not be utilized also for grounding lightning arresters.

Ground wires used for low voltage lighting or power circuits shall not be used also for grounding frames of equipment or wire runways operating on d. c. railway circuits or at voltages over 750.

Ground wires should be run separately to the ground itself from equipment and circuits of the following general classes:

1. Lightning arresters.
2. Secondaries of low voltage lighting or power circuits.
3. Secondaries of instrument transformers and instrument cases.
4. Secondary relay circuits where protective relays are operated from separate series transformers.
5. Frames of d. c. railway equipment or equipment over 750 volts.

(*b*) GROUNDS.—Lightning arresters shall not be grounded to the same artificial ground (pipes or plates) as circuits or equipments, but should be spaced as widely as practicable from other artificial grounds.

Lightning arrester grounds should not be made to water piping systems within buildings if circuits or equipments are grounded to such systems.

Where practicable, separate grounds should be provided for ground wires from equipment and circuits of the following general classes, particularly if artificial grounds are necessarily used:

1. Lightning arresters.
2. Secondaries of low voltage lighting or power circuits.
3. Low voltage instrument transformer secondaries.
4. Frames of d. c. railway equipment or equipment over 750 volts.

## APPENDIX B

## TABLES OF SAFE SAGS FOR HARD-DRAWN COPPER AND ALUMINUM WIRES

### TABLE 1

**Minimum Sags for Hard-Drawn Copper Line Conductors (taken from tables of 1911 report of Committee on Overhead Line Construction N. E. L. A.)**

| Conductor size A. W. G. | Temperature | Span lengths in feet | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 100 | 125 | 150 | 200 | 250 | 300 | 400 | 500 | 600 |
| | °F. | Inches | Inches | Inches | Inches | Inches | Feet | Feet | Feet | Feet |
| 4/0 Stranded | 0 | 2 | 4 | 5 | 9 | 14 | 1.8 | 3.5 | 6.5 | 10.5 |
| | 60 | 3 | 5 | 7 | 13 | 20 | 2.5 | 5.0 | 8.5 | 13.0 |
| | 120 | 5 | 8 | 12 | 20 | 31 | 3.8 | 7.0 | 10.5 | 15.0 |
| 2/0 Stranded | 0 | 2 | 4 | 5 | 10 | 16 | 2.2 | 5.0 | 9.5 | 15.5 |
| | 60 | 3 | 5 | 7 | 14 | 24 | 3.7 | 6.5 | 11.5 | 17.5 |
| | 120 | 6 | 9 | 12 | 23 | 37 | 4.5 | 8.5 | 13.5 | 19.5 |
| 1/0 Stranded | 0 | 2 | 4 | 5 | 10 | 18 | 2.5 | 6.5 | 12.0 | 19.0 |
| | 60 | 3 | 5 | 8 | 15 | 27 | 4.0 | 8.0 | 14.0 | 20.5 |
| | 120 | 6 | 9 | 13 | 25 | 42 | 5.0 | 9.5 | 15.5 | 22.5 |
| 2 Solid | 0 | 3 | 4 | 6 | 14 | 29 | 4.5 | 11.0 | 19.0 | 29.5 |
| | 60 | 4 | 6 | 10 | 23 | 43 | 6.0 | 12.5 | 20.5 | 31.0 |
| | 120 | 7 | 11 | 18 | 35 | 58 | 7.5 | 13.5 | 22.0 | 32.0 |
| 4 Solid | 0 | 3 | 5 | 9 | 29 | 66 | 9.0 | 18.5 | 31.5 | 46.0 |
| | 60 | 4 | 9 | 16 | 42 | 84 | 10.0 | 19.5 | 32.5 | 47.0 |
| | 120 | 9 | 16 | 27 | 54 | 90 | 11.0 | 20.5 | 33.0 | 48.0 |
| 6 Solid | 0 | 4 | 10 | 26 | 72 | 120 | 15.0 | 30.0 | .... | .... |
| | 60 | 8 | 19 | 36 | 78 | 132 | 16.0 | 31.0 | .... | .... |
| | 120 | 16 | 28 | 44 | 84 | 138 | 16.5 | 31.5 | .... | .... |

These are the sags at which hard-drawn, bare, solid, or stranded copper conductors shall be strung in order that when loaded with a load equivalent to the resultant of the dead weight of the wire plus an ice load one-half inch thick (1 inch added diame-

ter) and a wind pressure of 8 pounds per square foot of projected area on the ice-covered diameter of the wire at 0° F., the mechanical tension in the conductor will not exceed one-half of its ultimate tensile strength.

It is assumed that hard-drawn, solid, or stranded copper conductors have a modulus of elasticity of 16 000 000 and a coefficient of linear expansion of .0000096 per 1° F.

**TABLE 2**

**Minimum sags for stranded bare aluminum conductors (N. E. L. A. 1911 Report)**

| Conductor size A. W. G. | Temperature | Span lengths in feet | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 80 | 100 | 125 | 150 | 200 | 250 | 300 | 400 | 500 | 600 |
| | ° F | Inches | Inches | Inches | Inches | Feet | Feet | Feet | Feet | Feet | Feet |
| | 0 | 1 | 2 | 3 | 6 | 1.2 | 3.0 | 5.5 | 12.0 | 19.5 | 29.5 |
| 4/0 | 60 | 4 | 6 | 11 | 17 | 2.8 | 5.0 | 7.5 | 13.5 | 21.5 | 31.5 |
| | 120 | 13 | 18 | 25 | 32 | 4.3 | 6.5 | 9.0 | 15.0 | 23.0 | 33.5 |
| | 0 | 1 | 2 | 4 | 6 | 1.4 | 3.5 | 6.5 | 13.5 | 22.5 | 34.0 |
| 3/0 | 60 | 3 | 5 | 11 | 18 | 3.2 | 5.5 | 8.0 | 15.0 | 24.0 | 35.5 |
| | 120 | 13 | 17 | 25 | 33 | 4.5 | 7.0 | 9.5 | 16.5 | 25.5 | 37.0 |
| | 0 | 2 | 2 | 4 | 8 | 2.5 | 5.5 | 9.0 | 17.0 | 28.5 | 42.5 |
| 2/0 | 60 | 4 | 7 | 14 | 24 | 4.0 | 7.0 | 10.0 | 18.5 | 29.5 | 43.5 |
| | 120 | 14 | 19 | 28 | 38 | 5.5 | 8.0 | 11.5 | 20.0 | 31.0 | 44.5 |
| | 0 | 2 | 3 | 6 | 14 | 4.0 | 7.0 | 11.0 | 21.5 | 36.5 | ..... |
| 1/0 | 60 | 5 | 10 | 18 | 31 | 5.0 | 8.5 | 12.0 | 22.5 | 37.5 | ..... |
| | 120 | 15 | 21 | 31 | 43 | 6.0 | 9.5 | 13.5 | 23.5 | 38.5 | ..... |
| | 0 | 2 | 4 | 11 | 25 | 5.5 | 9.0 | 14.0 | 27.0 | 43.5 | ..... |
| 1 | 60 | 7 | 13 | 25 | 39 | 6.5 | 10.0 | 15.0 | 27.5 | 44.5 | ..... |
| | 120 | 17 | 24 | 36 | 49 | 7.0 | 11.0 | 16.0 | 28.5 | 45.0 | ..... |

These are the sags at which stranded aluminum conductors shall be strung in order that when loaded with a load equivalent to the resultant of the dead weight of the wire plus an ice load one-half inch thick (1 inch added diameter) and a wind pressure of 8 pounds per square foot of projected area on the ice-covered diameter of the wire at 0° F., the mechanical tension in the conductor will not exceed one-half of its ultimate tensile strength.

It is assumed that hard-drawn, stranded, aluminum conductors have a modulus of elasticity of 9 000 000 and a coefficient of linear expansion of .0000128 per 1° F.

# NOTES ON THE RULES FOR ELECTRICAL SUPPLY STATIONS AND EQUIPMENT, ELECTRICAL SUPPLY AND SIGNAL LINES, AND ELECTRICAL UTILIZATION EQUIPMENT

## 1. NOTES ON RULES FOR STATIONS

*Scope.*—A somewhat less general use of guards is allowable with station equipment, because of the more expert attendance, than with electrical equipment exposed to contact of attendants and others more or less unfamiliar with electrical hazards, as is usually the case in workshops, mercantile establishments, and similar places where machinery and apparatus using electrical energy are installed.

The rules are intended to be observed completely in new work and in considerable additions to old installations. The replacement of existing construction to secure compliance with the rules would in most cases, however, involve an unwarranted expense.

Some rules can be made effective at once and assist the safeguarding of existing installations without imposing any undue hardship and frequently with distinct benefit to service no less than to safety. Such improvements should be made as rapidly as possible, and a program should be arranged for future replacements and improvements by some reasonable schedule, having the approval of the administrative authority.

Guarding and grounding are usually feasible with existing equipment at no greater expense than would be required for similarly guarding or grounding new equipment. In such cases this protection should be provided. In other cases, due to very restricted space or the injury to service which might result from guarding, the provision of such protection may be impracticable. Such questions must naturally be left to the proper administrative authority for settlement.

**100. General Requirement.**

(*a*) No process of manufacturing can be carried on in the immediate vicinity of electrical generating equipment without mutually endangering both the persons engaged in manufacturing and those attending to electrical equipment. The continuity of service and life of electrical

equipment will also suffer, and sometimes the fire hazard is seriously increased.

(*b*) The necessity for continuous operation of generating equipment, together with the chances for sparking at contacts or connections, especially at switches, fuses, and brushes, makes the existence of inflammable vapors highly dangerous, even when the operator can endure such atmospheric conditions.

Moisture about equipment leads to frequent breakdowns, and these endanger both attendants and service. Attendants near live parts are also continually subject to leakage over damp surfaces and through deteriorated or moisture-laden insulations. In case of shock under damp conditions the better contacts increase the injury.

**101. Illumination.**

(*a*) The use of portable cords in the operation and repair of a station 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 or motors during operation, provision should be made of permanently fixed receptacles, conveniently located with respect to the equipment and safely accessible to the user. Provision of suitable short cords at convenient points will prevent (under careful management) the use of cords attached to distant receptacles and hauled about floors and other equipment.

Ladders and other makeshifts for obtaining access to lamps and other parts requiring attention have been responsible for many falls upon live parts or of severe falls from slight shocks.

(*b*) The operator should not be exposed to the danger of opening and closing switches (and other operations about live parts) in rooms suddenly darkened by the failure of current.

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

In certain cases oil lanterns may provide a sufficient emergency source of illumination.

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 to supply energy for operating relay systems and similar essential equipment. The addition 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.

The use of gas jets obtaining their gas supply from municipal mains is also often recommended.

The continuous use of the emergency lighting at all times so as to have two sources in use is having much support by operating companies.

**102. Enclosing Walls and Ceilings.**

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

**103. Floors, Floor Openings, Passageways, and Stairs.**

Falls, hitting obstructions, and other mechanical accidents are responsible for the greater proportion of all personal injuries in stations.

Particularly bad is the placing of lockers back of switchboards or in bus chambers. The mere unnecessary presence of persons in such places is dangerous; and the removing of clothing causes movements of the arms and stepping about, very liable to cause dangerous contacts or approach to live parts.

**104. Exits.**

Exits from rooms and working spaces about electrical equipment should be kept clear, since in case of fire or short circuit they provide not only means for escape but also means of quick access for repair.

Exit in more than one direction is particularly desirable back of switchboards, on narrow galleries, and in long passageways, since in case of dangerous arcing, smoke, steam, or other obstruction, exit in one direction may be cut off. A slight injury to the attendant such as burns or flashed eyes, or even slight faintness, may make the traversing of a long passageway to the single exit at the further end highly dangerous, since one is more liable under such circumstances to stumble against live or moving parts adjacent to the passage.

**105. Fire Appliances.**

Use of the ordinary sodium carbonate extinguisher on live parts endangers the operator, as does also the use of a hose stream of short length, and both may seriously injure the electrical equipment itself. Use of such liquids as carbon tetrachloride, on the other hand, entails no danger of shock, if the person does not bring the metal container into actual contact with live parts.

Some companies seal their protective apparatus which can not be safely handled about live parts. These seals can, of course, be readily broken, if circumstances warrant.

**110. General Requirement.**

(*b*) It is recommended that the rules of the National Electrical Code be complied with in the arrangement and protection of equipment and circuits, where not conflicting with these rules. In general these rules, by reducing fire hazard, also indirectly reduced the life hazard to some degree.

**111. Inspections.**

(*b*) Usually an initial inspection of electrical equipment, before placing it in operation, will be found desirable, however carefully the installation has been made, and a disinterested inspection is usually preferable to one made by the installing engineer, however competent and sincere. In some cases this inspection will be made by city or State administrators.

The value of systematically inspecting and testing apparatus and circuits after operation has been begun, can not be too strongly urged. Records should be kept of all defects noted, so that gradual deterioration of the system will be detected and injuries resulting from such defects will be avoided by proper repairs or replacements. The recording of failures also tends to improve design in new installations or extensions. Cleanliness is, of course, essential to delay deterioration.

**112. Irregularly Used Equipment.**

Equipment rarely used is frequently neglected and so becomes dangerous whenever energized. This can be avoided by systematic inspection.

Where equipment is disused but not removed, 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 may give an entirely false sense of security. To obtain reliable grounding requires very careful consideration of a number of conditions. Since the method is in general the same for grounding whether in stations, on lines, or in utilization equipment and circuits, and the requirements are necessarily considerably detailed in order to bring useful results, it is deemed best to place these detailed rules in a special appendix, A.

(*b*) Where conditions of dampness exist, 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 toward this result by making the frame of the same potential as surrounding objects.

(*c*) Such equipment as d. c. railway generators, rotaries, and switchboards, or d. c. arc machines and control boards, may sometimes present actually less hazard, if protected as required in rule 113 (c), than if grounded. This is especially true if ungrounded live parts are exposed as are 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 away from such frames. Reliance on a partial and variable insulation (such as masonry or concrete usually affords) between the frame and adjacent grounded parts, does not offer suitable protection either for attendant or equipment.

**114. Working Space About Electrical Equipment.**

Crowded machinery with either live or moving parts gives the most hazardous condition in stations. Because of restricted working space and inconvenient access, the equipment is liable to suffer from inattention, insufficient cleaning and consequent more rapid deterioration 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 is preferably inclosed by a guard rail. In either case conspicuous warning signs should be erected, prohibiting entrance.

(*a*) The spaces given should be considered as minimums and increased where practicable. The danger from contacts increases as voltage increases. Parts above 7500 volts unless isolated by elevation, 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, reliance may usually be placed on provision of liberal space for the attendant, good footing, careful instruction, and the infrequency of approach. Even with voltages above 7500 it is necessary to permit occasional approach to live parts, such for instance as disconnecting switches, by removal of compartment covers. The extra precautions and space requirements for such cases are given in rule 168 (*d*).

(*b*) 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 much increased. The spaces given 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 reckon on 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.

(*c*) In case of serious arcing or of slight injury, it is imperative that quick and safe escape should be provided from the space about any live or moving parts, which might further injure the person, if necessary to pass them.

**115. Guarding Live Parts.**

(*a*) 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 such with station equipment as to permit constant inspection, ready access, and quick repair or adjustment.

To avoid unnecessarily slowing down operation in emergencies of service, quick access is an essential; liberal working spaces are always to be recommended for the safety of the workman as well as for promoting continuity of service. For very high voltage parts, however, reliance on space is insufficient, and elevation or guarding must be resorted to. For lower voltages use of insulating floor coverings prevents the most frequent and dangerous form of electrical shock (circuit through the entire body).

Unless all the neighboring exposed live parts are of the same potential, however, inclosing or barrier guards will be usually a considerable further protection to workers. 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.

(*c*) Covers for meters, inclosing cases for switches, complete inclosure of terminals are among such guards as are suitable for live parts above 7500 volts. Or 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 is ordinarily considered as inadvertent with properly qualified persons, who alone should be authorized to work in spaces adjacent to live parts. 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 to take into consideration the possibility of persons inadvertently raising arms above their heads, thereby adding a foot or more to their height.

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 seven or eight feet to which a person can reach. It is probable that the elevations of live parts at different voltages required in the rule are a very small minimum when all these points are considered. Very tall persons will find the elevations insufficient, but the person of average height, observing due precaution will 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. In the installation rules of the Verband Deutscher Elektrotechniker very complete diagrams are required to be kept in convenient locations to assist the other means for identification, and labels are specifically called for at all automatic cutouts.

**120. Speed Control and Stopping Devices.**

(*a*) The importance of automatic speed-limiting devices for certain types of prime movers and motors should be better realized. More cases of bursting rotating parts from overspeed occur than of boiler explosions, which are regarded so seriously. With belted prime movers, steam turbines and water turbines, such limiting devices are particularly needed. Engines are frequently fitted with extra valves and independent control mechanisms. Water turbines in many cases have deflecting vanes oper-

ating to prevent overspeed. Generators carry a load which may become nearly zero by opening of automatic cutouts. The speed limit 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. The disconnection of motors is simpler and need introduce no mechanical strains.

(*b*) Separately excited motors are particularly liable to "run away," since their excitation may be entirely lost while the armature current still is maintained. Centrifugal devices operating relays which in turn actuate switches in the motor supply circuits, are most often utilized as means of protection.

(*c*) Similar means should be provided to prevent overspeed of certain types of electric motors. With direct-current motors having speed adjustment through field control, dangerously weak fields must be avoided, especially when the load is belted to the motor, or consists of generators which can have their loads suddenly removed by opening of automatic cutouts. No voltage release coils whether placed on starting rheostats or otherwise, in which the field circuit passes through the coil, are among useful means for preventing dangerous weakening of fields during operation. In some cases centrifugal devices will also be required.

(*d*) Use of more than one manual control device is desirable for stopping prime movers and motors. In emergencies this may save valuable time, and through use of relay control circuits a single valve or main switch can be readily operated from several points.

(*e*) The relative importance of control circuits, together with the natural frailty of the comparatively small conductors employed, make the use of conduit essential to assure reliability.

The use of closed circuits permits readier and simpler control of the stopping devices, and any chance open circuit gives evidence by lamp or bell connected in the circuit. With open circuits a break in the circuit may not be discovered until in emergency the control may be found inoperative. In some cases, such as motor-controlled switches or valves, open-circuit control must, however, be employed and the circuit must depend on careful protection to maintain it in operative condition.

**121. Deteriorating Agencies.**

Any hastening of deterioration by moisture, oil, or uncleanliness means danger of breakdown, which may occur while attendant is exposed. The insulation may also fail at the point where the attendant is handling it and cause harmful shock. The conditions of good contact and cramped

surroundings are also likely to augment the danger under such circumstances.

**122. Field Break-Up Switches.**

Usually a complete switch inclosure is to be recommended for field break-up switches, and these are being supplied by some manufacturers.

**124. Guards for Live Parts.**

(*a*) For the lower voltage machines the guarding is usually sufficient if it prevents touching live parts while standing on grounded parts. Insulated mats provide this protection. The most serious shocks are those where such contacts of the person are made that the current passes through the entire body. For higher voltages the somewhat less frequent shocks incurred by touching live parts while the other hand or some part of the arm is against grounded parts must also be prevented by use of suitable inclosing or barrier guards about the live parts.

The continuous insulating covering on conductors above 750 volts should not be regarded as a suitable inclosing guard unless periodically tested and not exposed to mechanical injury. Substantial guards are conduit, metal casings of equipment, fencing and similar inclosures, as per rule 115.

Suitable guards for live parts may be parts of machine frames or cases or may be insulated handrails preventing inadvertent contact with live parts.

In some cases screens or other shields adjacent to the grounded frame or other grounded parts which would be otherwise exposed to contact will be advisable to protect persons who may necessarily be engaged in adjustment of brushes, commutators, or other live parts.

(*b*) Machine frames necessarily operated ungrounded should be considered as alive, so far as danger to persons touching or standing on grounded surfaces is concerned. The reason for omitting ground connection is usually because of insufficient insulation between live parts and frame to permit of reliable operation were the ground connection made. Insulating platforms or mats are therefore required about such machines, since their frames may become alive through leakage at any time.

Machines coupled together offer the same danger to a less degree even where insulating mats are provided, in that 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 by bonding or are so isolated or barriered that no person can inadvertently touch both frames simultaneously.

Exciters for machines with ungrounded frames are subject to the potential of those machines through the frame. If this can be 1200 volts 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. This danger may be minimized by identifying both exciter frame and circuit as 1200 volt or 2400 volt equipment or by grounding the exciter frame and circuit. The grounding of the exciter frame and circuit may be objectionable for the same reason that led to the absence of ground connection to the frame of the principal machine, but this thoroughly illustrates the dangers and difficulties which may be entailed by omitting ground connections from exposed cases and frames.

**130. Isolation.**

The danger from personal contact is increased over that in other station rooms by the presence of electrolyte and consequent decreased contact resistance. The danger from sparks in the explosive gas given off by storage batteries in charging is also serious. Several explosions with accompanying injuries are of record.

For these reasons such equipment should be made inaccessible, except to qualified persons, if voltage exceeds a low maximum or the size of the battery is such as may produce considerable volumes of inflammable gas.

**131. Ventilation.**

With large equipment, special ventilation by fans may be necessary. Pockets in ceiling spaces above door and window openings should be avoided.

**132. Covers.**

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

**133. Insulating Supports.**

Separate insulating supports for cells prevent leakage along surfaces from one cell to another, which might result in dangerous arcing. They also tend to prevent adjacent floors from becoming alive.

**134. Guarding Live Parts.**

Some batteries are badly arranged by having cells adjacent, between which the highest voltage (that of the entire battery) exists. This can be obviated by proper connection, and the danger to attendants and to the service alike reduced proportionately.

The use of a permanent platform in the working space adjacent to a storage battery is always desirable, but entails some trouble in cleaning floors. At the higher voltages this trouble is always warranted because of the extra danger.

**140. Oil-Insulated Transformers.**

The rapidity with which oil fires spread makes such fires unusually hazardous to life, and the danger to other equipment is also greater than with fires of other materials ordinarily contained in station structures. The drainage provided should be ample to empty the cases and the room very quickly, so that the fire can not extend to other equipment or to the station structure.

One serious fire from this cause occurred in 1908 in a western State, where, within 15 minutes, the station, although of stone with steel trussed roof, was completely destroyed, and attendants had barely time to escape. Over $70 000 loss was sustained.

**141. Current Transformer Secondary Circuits.**

The opening of a current transformer secondary may result in breaking down the insulation from the primary, and in any event may cause serious arcing at the point of opening. If suitable short-circuiting devices are provided, chance openings are less likely to occur when instruments are 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. All such circuits should be so installed as not to be subject to mechanical injury as the conductors are usually small and consequently frail.

**142. Guarding Low-Voltage Circuits of Instrument Transformers.**

In some cases, as with Tirrill regulator control, proper and reliable operation necessitates the freedom of the entire low-voltage circuit from ground. This circuit, if so left ungrounded, may at any time take up a high voltage by reason of leakage or induction. For this reason it must be run in all respects as required for high-voltage circuits, and clearly distinguished by suitable markings from other low-voltage circuits with which it may be associated.

When rotary converters are supplied from transformer secondaries, no ground connection can be made on the a. c. side if one exists on the d. c. side.

During the period after the transformer is connected to the high-voltage supply and before the secondary is connected to the rotary converter, the secondary is necessarily ungrounded. For this reason it should be so treated and sufficiently guarded at the few switches and other parts where it is not isolated by elevation or thoroughly inclosed.

**143. Guarding or Isolating Live Parts.**

Transformer leads impose in general the same hazards and require the same isolation or guarding as other live parts (treated in rules 115 and 116).

**144. Grounding Transformer Cases.**

It is usually feasible and desirable to ground transformer cases, but with some bus type current transformers and similar equipment, isolated or guarded against contact by persons, the grounding is unnecessary and undesirable. Where the case is not grounded, it should, of course, be considered as liable to leakage from the high-voltage winding.

**150. Protection in General.**

(*a*) 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 sheath may be necessary for wires with insulating covering.

For the best protection of persons in the vicinity, or engaged in operating switches on circuits, the 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. Several recent 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 instance named as exception 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 exists.

(*b*) Where conductors are necessarily grouped rather closely the danger from spreading fire originating in slight arcs becomes considerable, unless the insulation is made incapable of supporting combustion.

For large cables Portland-cement plaster, at least ½ inch thick, over a wrapping of rope, has been found effective.

Asbestos sleeves, taping, or use of 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 as are at all conducting, must of course be stripped away from the bare terminal.

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

**151. Isolation by Elevation.**

Conductors in locations where persons are regularly in attendance may, even if well insulated, be dangerous through charges on their exterior surfaces, especially where flame proofing is used which is not an insulating substance and the voltage of the conductor is high. Where exposed to contact of persons, such conductors are also exposed in some degree to mechanical injury, and this supplements the personal hazard as a reason for requiring protection other than their insulating covering.

**152. 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.

(*a*) 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.

**153. Guarding in Hazardous Locations.**

(*a*) The slightest arcing at bad joints in conduit may be serious in locations where inflammable gas is present.

(*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.

**154. Pendants and Portables.**

The use of long cords and of cords attached direct to bus bars, switch terminals or blades, and similar makeshifts, are causes of frequently severe burns, eye injuries, and not a few fatalities. The importance of carefully planning the installation to reduce such abuses in practice is becoming better recognized than formerly.

**155. 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 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 not left alive without competent supervision.

**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.

**161. Hazardous Locations.**

In underground stations, subways, and similar locations, 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 gasses without. Air-tight cases or cases with carefully screened passages have been developed to meet such conditions.

**162. Where Switches are Required.**

(*a*) Where all leads of a circuit are opened at one operation service is better safeguarded and operation more prompt. In some cases large currents will be more safely interrupted than with single-pole interruption.

(*b*) In some cases both motors and the machines they drive may be so inclosed or otherwise arranged that the operator is not endangered by their starting nor by their continued operation. In these cases switches within his control are unnecessary (if undesirable from other considerations). Motors driving inclosed fans or rotary pumps would come under this exemption.

**163. Character of Switches to Use.**

(*a*) Interlocking may be arranged by use of latches held in place by the magnetic field produced by the current flowing.

(*c*) Leakage across the break of oil-break switches may be sufficient to cause dangerous shocks to persons in contact with circuits supplied through them, and disconnectors should be used to obviate this trouble.

Switches connecting busses, or otherwise so located that they can be alive from both sides, should be protected by air-break disconnectors at either side, and this is common in good practice.

**164. Where Automatic Cutouts are Required.**

See note under rule 150. Distributed resistance or suitable regulators might satisfactorily limit the possible current in circuits from generators or batteries in some cases.

**165. Arrangement of Automatic Cutouts.**

(*a*) Except for fuses at low voltages, the danger of 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 the fuse in a live clip, through blowing of the fuse by short-circuits beyond it, is a serious one.

(*b*) Many persons are annually burned by replacing fuses in live terminals or by sudden blowing of fuses or circuit breakers near them.

**166. Suddenly Moving Parts.**

In some cases operators have been severely injured by being struck by levers and handles of circuit breakers.

**167. Grounding Noncurrent Carrying Metal Parts.**

See note under rule 113.

**168. Guarding Live Parts of Switches and Automatic Cutouts.**

(*a*) The best safeguard from contact with live parts of a switch is the operation of the switch by remote control. Another method for avoiding danger of contact is provision of a casing in which all parts of the switch are inclosed.

(*b*) For low voltages, the insulating handles and a disk or other barrier so attached to the switch that the hand is protected reasonably against slipping against the live part, and against burns from arcing at the switch contacts may provide sufficient protection. With large switches, however, even at low voltages, remote control or casing is recommended.

(*c*) The common cause of shocks (contact with live parts while standing on grounded surfaces) is removed by use of suitable insulating floors, and unless switch is incased during operation, even although guarded insulating handles are provided, insulating floor protection should be also provided for switches over 150 volts to earth.

**171. Convenient and Safe 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 on live parts.

**172. Safe Location.**

Neighboring machines should never encroach on the working space (as required by rule 179) and, since rapid control is necessary, the working spaces at the operating platform should be very liberal, and permit the operator to give full attention to his special duties on the switchboard itself.

**173. 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 purposes.

**174. Arrangement and Identification.**

Where bus chambers in uniform 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.

**175. Illumination.**

On account of the emergencies arising in switchboard operation and the necessity for rapid and at the same time sure and safe control, illumination is necessary at all times, and when natural illumination fails, artificial means should be instantly effective. 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.

**179. Guarding Live Parts.**

(*a*) Fencing is preferable to dependence on the setting apart of the space, as it leaves the operator free to give full attention to operation. The placing of switchboards on galleries, of course, accomplishes the same purpose.

(*b*) Insulating floors have few of the disadvantages of unevenness and unreliability which mats and platforms possess, and, in the dry, clean surroundings usual with switchboards, afford effective protection to the operator touching only one live part of moderate voltage. Various materials, such as albarene stone, soapstone, slate, and marble, are satisfactory. For insulating mats or platforms, a depressed section of floor is advisable, so that their edges are flush with the floor surface itself.

(*c*) Injuries from contact with live parts between which a voltage over 750 exists, or from one such part to ground where the voltage to ground

exceeds 750, are so serious and have been so frequent that reasonable isolation by elevation or suitable guarding 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.

(*d*) See rule 114.

(*e*) Plugs with insulating sleeve guards are available by which exposure of live parts at front of plug-type switchboards may be entirely obviated.

(*f*) In good practice, meters operating on high voltage circuits are provided with outer metal and glass covers, permitting ready attention without danger of injury to the attendant.

**180. When Required.**

The failure of equipment, due to lightning, entails serious hazard to operators as well as to the service. The protection afforded by arresters is therefore desirable from both these considerations.

**182. Disconnectors.**

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

**183. Location.**

Small arresters may be placed within noncombustible compartments, and so avoid short circuits between conductors and injury to neighboring equipment, by arcing at arresters during discharge.

## 2. NOTES ON RULES FOR ELECTRICAL SUPPLY AND SIGNAL LINES

### SCOPE OF THE RULES

The rules for lines like the rules for stations and utilization equipment are intended to apply to existing installations so far as is reasonable, as indicated by the introductory statement. In the placing of guards and grounding of parts there is just as much need for complying with the rules in old equipment as in new, and usually no greater expense is involved in doing so.

The rules do not contain as many detailed requirements as are required for construction specifications or are often contained in safety rules of European countries. The aim has been to include the more important features of safe construction, and leave the widest practicable freedom with respect to the methods of obtaining the specified results. Many of the rules say that certain things "should" be done, by which is intended

a strong recommendation, but "should" does not convey the mandatory meaning of "shall." In some cases certain things are explicitly stated as recommendations.

The various specifications mentioned are given as references, but are not to be considered as a part of these rules.

**200. Design and Capacity.**

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 as this part of the code applies chiefly to public utilities, it must be remembered that the public in the end pays whatever extra cost is caused by the safer and better construction required, and hence the public may rightly require a somewhat higher degree of safety than it could under other conditions. However, since the circumstances vary so widely it is necessary that the rules admit considerable latitude in construction of lines. 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 support safer and more substantial construction than can be afforded or is needed in sparsely settled communities.

**201. 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.

**202. Inspections.**

Frequently undesirable or unintended conditions creep into construction which are not discerned by the superintendent or foreman locally in charge of the project. Hence it is advantageous to provide a final and formal inspection by a competent authorized person, other than the one who has superintended the construction. Such an inspection may in some cases be made by the State or municipal authority.

Existing installations and their protective guards and equipment provide safety and satisfactory service only when maintained in thoroughly good operating condition.

Lines temporarily out of service, as for example long loops to consumers, and feeders to sparsely settled localities, are frequently the cause

of accidents, through generally poor maintenance. To reduce this class of accidents to a minimum it is necessary to maintain and inspect them as though in regular service.

**203. Records.**

Detailed records relative to certain problems of construction and maintenance would greatly improve conditions from a viewpoint of safety. Repairs made necessary by recurring defective conditions which affect safety should be recorded. Frequently it will be found that such records will greatly improve service conditions as well. It is not, however, the intent of this rule to require a record of the usual routine maintenance work.

**204. Isolation, Guarding, and Accessibility.**

In general, electrical supply lines would be so arranged by elevation above accessible places, or so protected, that the general public and unauthorized employees will not be subjected to unrealized hazards. However, it is frequently the case that outdoor substations, for example, have not been given effective isolation. Also, accidents occur through not providing lines with sufficient clearance from accessible positions such as bridges, platforms, and the like.

Ungrounded noncurrent carrying metal parts of pole line equipment such as guy strands, arc light and trolley span wires, arc light suspension chains, disconnecting switch cases, metal conduits protecting vertical runs of cable, and much other equipment should, unless well isolated, be provided with adequate insulating protection. Suitable strain insulators properly placed in a guy strand are considered as providing a suitable guard for such a case. It is frequently necessary to provide protection over metal conduit and many have found it satisfactory to use a substantial wooden covering.

This requirement for guards applies to ungrounded parts which are accessible. Grounding in conformity with the rules outlined is a satisfactory method for avoiding the necessity for mechanical protection which is sometimes cumbersome.

**207. Identification.**

Electrical supply lines should be arranged systematically to provide ready identification. It is perfectly practicable to construct and maintain supply circuits in a manner such as to assure their ready identification. This not only precludes service interruption by mistakes but assures the greatest safety to workmen.

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 the pole pin position of a certain crossarm 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 identification, by means of insulators of various colors or materials, have been devised. When properly maintained such an arrangement is very satisfactory. Another suggestion frequently followed is to indicate on the cross-arm, opposite the pin position, the character of the conductor according to a letter or number code.

**210. Separation of Lines to Avoid Conflict.**

**211. Arrangement of Lines When in Conflict or Carried on the Same Supports.**

Conflict may be due to an overbuilding or a direct encroachment where the lines are maintained at about the same levels. Such conditions frequently arise in narrow streets or alleys, or where space is otherwise restricted.

Wherever practicable a sufficient clearance should be provided between adjacent supply lines or a supply line and a signal line, to assure that in case of failure of either system, by the poles overturning, the conductors of the higher line can not fall upon those of the lower line. Cases will frequently be found where the full separation of a narrow street would not provide the above, especially with tall poles. Under such conditions a concession is made in the rule to two-thirds of the clearance otherwise required. A narrow alley is not considered as a street.

When the foregoing conditions, as to separation, can not be met it may be found that another satisfactory route can be utilized for one of the pole lines.

The primary object of this rule is not to secure continuity of service or freedom from inductive disturbances, but to provide protection from crossed wires. The separation or better construction is required as a protection to life both for the public and line workers.

**212. Required Grades of Construction.**

An added risk of personal injury is present at points where a supply line crosses over a signal line, or vice versa, at crossings of one supply system over another, or where supply or signal lines cross over a steam railroad. In urban districts the hazard from fallen wires is greater than in rural districts and superior construction should be provided to reduce the hazard as much as practicable.

If a heavy telephone lead is involved at a crossing with 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 provided, of course, by the fuses, within rather definite voltage limits, but in general this limit is much below the operating voltage of some of the existing systems of distribution in large cities and below almost all transmission voltages.

The failure of a power system crossing above another will usually subject the equipment of the lower system to abnormal electrical strains. Should these cause failures of apparatus, 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 induce various hazards. Trainmen know certain hazardous locations, such as low-roofed tunnels and low bridges crossing over the tracks. These obstructions are readily perceived on account of their size and outline, while a wire would be rather hard to see. A wire stretched over railroad tracks should always provide 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. Further, wires which would frequently fall across the signal wires used for controlling train movements may cause serious accidents through inability to use the signal system.

In urban districts the great number of persons constantly exposed to fallen wires 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 conductor where the population is but 10 per square mile. A study of recorded accidental deaths indicates that the mechanical failure of conductors, which fall directly within reach from the ground or involve other circuits, is a prolific cause of accidents.

It is necessary to indicate certain grades of mechanical construction to reduce as far as possible the hazards outlined above. The required mechanical construction is intended to provide a suitable factor of safety with a certain assumed mechanical loading of the conductors and poles due to ice, wind, and temperature which has been generally accepted by engineering practice throughout the United States as reasonable for the conditions and hazards experienced. In general, this loading is very much smaller than is specified in European countries. The voltage gradations noted closely follow those set forth by the orders of some

of the State commissions dealing with such conditions, and meet the general approval of electrical engineers. While some communities have seen fit to set voltage limitations beyond which overhead lines are prohibited it has seemed undesirable to include such restrictions in these safety rules as this might tend to delay useful extension of electrical service and so continue in use more hazardous light and power agencies. The term "urban districts" (thickly settled communities) is not precisely defined. The authorities administering the rules will need to define it further. Certain State commissions have already done so through the administration of their automobile laws, while it has also been defined at other times through the police and fire ordinances.

**213 Requirements for Construction and Maintenance of Lines Designated as Grades A and B in Table I.**

Having set certain grades of construction to be installed for overhead systems at points where hazards are serious, it becomes necessary to define these grades.

As indicated in the preceding note the hazard from fallen wires is considerable. Certain sizes of wires must be assumed as minimums, since below them the wire is so small that it is frequently damaged in handling during construction or it will not successfully withstand ordinary service conditions. Then, too, a wire may be of sufficient size and strength to be adequate and yet not be properly installed. At the time of installation, it should be given such a sag as to insure that under the most adverse condition of mechanical loading due to wind, ice, and temperature, to which it can reasonably be considered as subjected, the tension will not exceed an assumed safe value somewhat less than the elastic limit of the conductor material.

When installed with too small a sag a conductor will fail due to exceeding its tensile strength under the adverse loading condition. If given excessive sags the smaller sizes of conductors are readily blown about by the winds. This frequently causes short circuits and burn-offs of line conductors. Not infrequently short circuits affecting lines being supplied by great generator capacity cause violent swinging of line conductors, and short circuits between line conductors have been caused in this way. Trouble from swinging together may be reduced by increasing the pin spacings, shortening the spans or using heavier conductors with the original pin and pole spacings. (See note 250).

Soft drawn solid copper wire, with weatherproofed braided insulation is extensively used for urban distribution circuits. It has several characteristics which make it valuable for such work, but its mechanical strength is only about half that of hard drawn copper, and it has no

really well defined elastic limit. To a certain extent the ductility of soft drawn copper makes it more valuable as a line conductor. If subjected to abnormal mechanical loading it gradually stretches and increases the sag and thus relieves the condition automatically; but it must be frequently drawn up to the normal sag or crosses will result. Care is therefore necessary in stringing soft copper conductors to provide against their being drawn too tightly, while equal care must be taken to avoid leaving them too slack, thus allowing them to swing abnormally.

Aside from indicating a minimum size of conductor from a mechanical point of view, it is advisable also to limit the size from the voltage viewpoint, as an even greater security against falling is desirable for conductors operating at the higher voltages. This is one reason why small conductors should be avoided for high voltage lines.

Conductors for overhead transmission and distribution systems, excepting those operating at the higher range of transmission voltages, are normally supported by insulators mounted upon pins. With conductors of the same size and material in place, and drawn to a uniform tension, the stresses upon pins, crossarms and poles are balanced. However, the failure of a conductor introduces a very complex unbalanced condition affecting the entire supporting structure.

Through its design the insulator will take its load as a crushing force at the tie groove and be amply strong. However, the insulator pin acts as a beam whose length is equal to the distance from the top of the cross-arm to the point of attachment of the tie wire. The cross-arm also acts as a beam whose length, 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 for attaching (tying) a conductor to an insulator. The insulator pin most frequently used in urban districts is the so-called standard locust pin with a top diameter of 1 inch, diameter of shank 1½ inches, length of shank 4¼ inches, and an overall length of 9 inches. The results from several sources indicate that this pin will normally withstand, during a reasonable life, the loading due to a tension of 1500 pounds in a conductor when applied at the tie-wire groove of the insulators most generally used. 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.

Conductors of the smaller sizes should usually be drawn to such a mechanical tension that under the most adverse conditions of mechanical loading this tension will not exceed one-half of the tensile breaking strength. With normal spans and pin spacings this stringing will reasonably assure against conductors swinging together. However, for conductors where the tension would exceed 1500 pounds (the strength of the pin), additional strength must be provided by the use of double pins, pins of greater strength, suspension or strain type insulators, or the sag of the conductor must be increased by such an amount as to assure that the maximum conductor tension will not exceed the value assigned above.

An accumulation of a layer of ice on a conductor, together with a heavy wind, or either condition alone, is equivalent to increasing the weight of the conductor and therefore increasing the strain necessary to support it. Temperature changes also modify the strains considerably.

These rules consider that a conductor may at times be required to carry a layer of ice one-half inch thick radially (that is, the diameter becomes 1 inch greater than that of the conductor) and at the same time be subjected to a wind pressure of 8 pounds per square foot of projected area while the temperature of the surrounding atmosphere is 0° F. In many localities this assumed loading would be too severe. This is especially true in the South, but in other regions the assumption is too lenient. Proper modifications of this assumed loading condition will need be determined by the administrative authorities for the various localities where these rules are in operation, but should be chosen only after collection of weather data over long periods and reasonably wide territories.

**220. Conductors above Railways and Highways.**

The clearances of line conductors, and other line equipment, above railroads, streets and other spaces as specified by the various State commissions have differed widely, and in some cases have been excessive, as, for example, a clearance of 40 feet above a railroad track. A system of reasonable and adequate clearances permitting at the same time strong and economical construction, should be provided and maintained under the most adverse condition, whether that is due to ice loading in winter or high temperature in summer.

It has appeared reasonable that at crossings over steam railroads a clearance of 25 feet should be provided as a minimum for all conductors, other than trolley contact wires or feeders, for which a minimum clearance of 21 feet (or in some cases 22 feet) is permissible.

When crossing over or passing along streets or alleys or roads in urban or rural localities, it has been commonly suggested that 20 feet of clearance be required for signal, guy, span, overhead ground wires and service loops. However, the general practice for the overhead construction of trolley systems almost universally calls for a nominal clearance of 18 feet above the streets. It would appear, therefore, that 18 feet should be adequate also for the former classes of wires. From general practice and opinion it would seem that 20 feet is sufficient clearance for line conductors up to and including 7500 volts, while not less than 25 feet is desirable for voltages above 7500 volts. These minimum clearances should be provided and maintained, for their adequacy has been well agreed upon. The advantages of uniformity of requirements in the various parts of the country will be found to warrant adoption of very reasonable minimums.

**221. Conductors Crossing Others.**

At crossings of one system of electrical conductors above another it is necessary to provide adequate mechanical clearance between the two systems involved to insure that the conductors of the two systems do not come into contact with each other under any reasonable conditions. In case such a contact takes place, that system which normally presents the less hazardous situation becomes extremely dangerous to men working upon it or consumers of the service it renders, as its usually effective devices for protection are not sufficient under the new condition.

The minimum clearances provided for in Table 3 are those generally considered as adequate and reasonable.

Indicating lengths of spans of 100 feet at crossings is based on the fact that conductors of sizes ordinarily used if in long spans have considerable movement, blowing up when there are severe winds and sagging down in hot weather or from ice loading, thus making it possible for conductors of long spans to dangerously reduce the small distances named for short spans.

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 are given so little clearance normally over guys, span wires, and messengers that with summer temperatures or ice loading they come into contact. Also, in the case of messenger wires supporting telephone or other cables it is necessary that safe separation be provided, so that workmen out on the cable messenger are assured a free access to all parts of the span.

**222. Increase in Clearances Between Conductors for Spans Exceeding 100 Feet.**

A method is outlined whereby additional clearance is provided when a crossing is so arranged that the sum of the distances measured along the two lines from the nearest supporting structures of the crossing to the point of intersection exceeds 100 feet. Two coefficients for increased clearance are introduced, as less total clearance is necessary for lines using copper conductors than for those using aluminum conductors, due to the differences in weights, diameters, and sags.

**230. Separation of Line Conductors of Each Voltage Classification.**

The rule given for the separation of line conductors will determine the minimum distance for moderate spans and sags. The minimum distances given in Table 4 apply to short spans. For very high voltages and long spans the clearances given either by the table or by the rule are insufficient. In this respect rule 230 is not entirely satisfactory. Criticism and suggestion are especially invited as to the best way of specifying line clearances for very long spans. This problem is the more serious as these long spans are mostly used with very high voltage lines.

**231. Lateral Working Space Between Line Conductors.**

To safely work upon the conductors supported by a pole or structure, sufficient horizontal space must be provided between adjacent crossarms. In order to avoid placing taller poles, thus providing an opportunity for more clearance, it frequently happens that a utility seriously reduces this working space between cross-arms. 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 the placing of temporary protective devices before he can safely proceed with work.

**232. Vertical Clearances Between Line Conductors of Different Circuits Operating at Different Voltages.**

**233. Clearances for Suspension Insulators.**

The conductors of circuits, supported by pin or strain type insulators, operating at different voltages and maintained at different cross-arm positions on the same pole should be maintained so as to provide liberal minimum clearances (center to center of crossarms) in order to minimize accidents due to their swinging together during storms.

The indicated rule provides proper clearances for long spans and large sags, but these would usually be too small for short spans. Therefore, it is necessary to indicate minimum values and such are provided in Table 5. In some cases these are in excess of the clearances required at crossings. This is because a line of considerable length presents a greater hazard with small clearances than at a crossing.

As noted in connection with the table the reduction in clearance which would result from differences in conductor sags if all conductors were given the same factor of safety should be prevented by rearrangement of crossarm spacings or conductor sags, but no conductor should have its safe sag reduced to accomplish this.

Conductors supported by suspension insulators have a much greater movement which is dependent upon the length of the string of supporting insulators. General practice indicates that by increasing the clearances over those used for pin-type insulators by an amount equal to one-half the length of the string of insulators provides ample clearance.

**234. 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 side or portion of the pole as the climbing side.

Where necessary to maintain vertical or lateral conductors on a pole they must be so arranged that they will not obstruct the climbing space vertically along the pole or the horizontal working space between cross-arms. This may be accomplished by placing the verticals in suitable protective coverings attached to the pole on the side opposite the climbing side, or bringing them down at the outer end of the crossarm as is frequently done. Laterals would be maintained on the side of the pole opposite from the climbing side and at the same horizontal planes as the cross-arms.

It is frequently desirable to install pole steps on certain poles and when this is done their free and safe use must not be prevented through improper location of verticals.

To keep the climbing space clear it is necessary that vertical conductors, unless specially protected as noted, maintain a stated minimum clearance from the pole center.

The close proximity of supply and signal conductors always introduces a hazard to workmen. It has been generally agreed that all vertical conductors passing by signal conductors must have a continuous insulating conduit or suitable protection over them for a distance of not less than 80 inches, viz, from a point 40 inches above to a point 40 inches

below the signal conductors passed by. If the supply conductors operate at over 7500 volts such a covering shall be provided from the ground line to a point 40 inches above the signal conductors except that the first 10 feet above ground may be of metal conduit.

**235. Clearances from Buildings.**

The efficiency of firemen is much reduced when hampered by the presence of electrical conductors. This is due to mechanical interference as well as the fear of serious electrical shocks. The clearances indicated will permit more effective work of firemen and at the same time reduce other life hazards.

Frequently it is the practice to maintain secondary conductors on racks or brackets along the rear walls of houses. This should not be permitted when the voltage is above 750 volts. The conductors should be made reasonably inaccessible for any voltage, as by placing near the eaves out of usual reach or else they should be positively guarded.

**242. Insulating or Mechanical Guards for Guy and Span Wires.**

The attachment of a guy to a wooden pole has the effect of bringing the ground up to the pole. A workman may come in contact with this guy and a live electrical conductor at the same time. Suitable insulators installed in the guy afford protection to the workman on a pole and to the pedestrian below as well as reduce the undesirable electrical effect due to grounding the pole so near to the conductors. Such insulators are not necessary in guys attached to metal poles as the whole structure is grounded, while for guys attached to poles supporting conductors operating at over 20 000 volts they are inadvisable due to their unreliability.

When guys from a pole carrying signal conductors are exposed to overhead electrical supply conductors suitable insulators shall be installed in such guys the same as for guys supporting a pole carrying supply conductors.

When wood poles carry only a lamp or trolley suspension wire a single insulation at the hanger may be sufficient, since the wood pole provides a long path to ground of high resistance and the public is endangered only by leakage to ground. However, injuries have occurred through such leakage from series lamps and it would appear that double insulation is advisable in all cases for circuits of the higher voltages.

The insulating value of a wood pole, especially when damp, is not to be depended upon. This should be especially considered when it is necessary for workmen to come near the brackets or span wires supporting a series lamp or trolley wire. General practice normally provides double insulation between the lamp or 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 also carrying the lighting or trolley circuits, their lives should be as adequately protected as the commercial service maintained on metal poles, and double insulation (not considering the pole as one) should be provided even with wood poles under such conditions.

Accidents frequently occur due to persons inadvertently running into a guy wire. To aid in reducing these accidents guy guards should always be provided; they are frequently required by certain State and municipal regulations.

**243. Trolley-contact Conductors.**

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 10 feet to any generally accessible place.

**250. Poles or Towers—Clearances and Identification.**

Wood pole spacing should be limited in municipalities for several reasons, among them the impracticability of side guying, the popular objection to considerable sags, and the necessity for utilizing poles for service drops to buildings served. The fact that soft-drawn copper possesses so many advantages in ready handling has led to its general adoption where much handling is necessary during service. Long spans of this material can not be maintained with small sags, as the wire will stretch in winds and sleet storms. If the span is too great wires may swing together, and the wider spacing of pins to meet this trouble is impracticable from considerations of appearance, proximity to buildings, and standardization of supply stocks. (See note 213.)

The ready identification of poles, towers or other structures supporting electrical conductors is desirable. European requirements often demand that the ownership be indicated on each structure together with its serial number However, in many cases a systematic scheme of indicating the utility operating a pole line can be carried out without marking each pole, but by marking, say, every fifth pole, or one at every branch line.

**251. Guys and Anchors.**

The use of a single solid guy wire is to be discouraged. A rather slight injury will frequently destroy its usefulness. The short bend where a guy passes through the eye of a guy rod produces an excessive strain

which may be greatly reduced by the use of a guy thimble between the strand and the rod.

Where the heavier sizes of guy strand are used they frequently cut very deep into wood poles, thus reducing the strength of the pole. Guy shims or plates placed under the strand will distribute the load over a large surface of timber and prevent cutting. However, when shims are used the guy may slip down on the metal surface; hence guy hooks should be used to prevent slipping, particularly for supporting guys with a short lead.

Frequently anchors for guys are subject to severe electrolysis conditions and anchor rods practically destroyed. This may be prevented by using suitable insulating blocking between a guy and a metal pole, or strain insulators in such guys. Guys 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 the lead of the guy (horizontal distance from pole to attachment of guy to anchor) should, where practicable, not be less than two-thirds the height above ground of the attachment of the guy to the pole, and the anchorage to which the guy is attached should be capable of withstanding the load to which it will be subjected. The anchor rod and anchorage are subject to much more rapid deterioration than the strand; hence they should be of the best material and workmanship.

In general anchor rods are of such lengths that their full strength is developed by the anchorage, if installed in solid earth only when about 12 inches of the rod projects 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 strand.

When lining up the pull of a guy 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.

**254. 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 750 volts this space should be increased to avoid necessity

for either crowding against conductors or placing temporary shields on them. Great effort should be made to maintain a liberal climbing space on buck-arm poles, and this will require omitting use of one pin on each arm adjacent to the climbing space.

So far as practicable a utility should maintain its poles free from posters, bills, tacks, nails, and other unnecessary obstructions. Such articles attached to a pole may cause a fatal injury to a workman in falling who otherwise would not suffer severely by falling along a clear pole.

**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 over private property to serve neighboring customers.

**256. Transformers, Regulators, Lightning Arresters, Lamps, Lamp Supports, and Similar Equipment.**

An effort is being made to provide sufficient space upon a pole for the safety of the workmen. It must not be stopped up with transformers, regulators, switches, and similar equipment. Where necessary to hang close to the pole they should be hung on the opposite side of the pole from that which has been designated as the climbing side at that particular part of the pole.

**260. Material and Minimum Size.**

Unless the galvanizing of line conductors is of a high grade and the construction is effectively maintained the smaller sizes of solid drawn iron and steel wires depreciate rapidly, while solid aluminum wire fails due to crystallization at the support due to repeated bending. Because of these characteristics the use of solid iron, steel, or aluminum conductors is prohibited under the conditions outlined in this rule.

**261. Tie Wires or Fastenings.**

As outlined previously the maximum allowable tension which may be permitted in any conductor has been set at 1500 pounds. The fastenings of a conductor should be such as to withstand this load satisfactorily.

Ties or conductor fastenings which bring sharp edges, burrs, or sharp angles into contact with a conductor are to be avoided as they are causes of serious injury to conductors.

**262. Marking Insulators.**

It is desirable that insulators be readily identified. This is of value to the utility purchasing them as it provides a means for knowing that the materials purchased should satisfactorily fulfill given requirements. This marking is the equivalent, in usefulness, of the name plates indicating transformer, motor, and generator ratings.

**270. Location.**

The municipality will usually prescribe the general location of an underground insulation, 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, which are difficult to provide in congested districts.

**272. Accessibility.**

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.

**273. Mechanical Details.**

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.

**274. Manhole Covers.**

A cover for a manhole or handhole which has sufficient weight to hold it in place is considered secure. Locking or clamping is not required, although frequently advisable. A special hook or bar is frequently provided for opening a manhole, while some covers have a recess in the top crossed by a bar, and a spring snap attached to a strap is hooked onto this bar, thus providing a special and safe means for removing the cover.

**277. Installation of Ducts.**

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 the duct. 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 capacity 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.

**280. Location and Identification of Conductors.**

A distance of 6 inches between a cable and the floor or roof of a manhole is desired to provide suitable working space and insure thorough inspection. It should be provided wherever practicable. It is considered that signal conductors for the service of the general public should be maintained separately from those for supply purposes. Failure of a supply cable in a manhole containing signal conductors would distribute the hazardous condition widely.

Cables need to be safely accessible at all times in a manhole. It should not be necessary for a workman to climb on or through a group of cables in order to gain access to another one.

**281. Mechanical Protection and Support.**

The insulating coverings of all cables or conductors shall be protected by a waterproof covering. In general, a continuous lead sheet 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 con-

ductors 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.

**282. Spacing.**

It is frequently necessary to conserve duct space as much as possible, and for this reason it is believed that cables and conductors should be arranged as outlined. Those which have been permitted to be grouped together are normally provided with adequate protective devices in case trouble develops in any of them. Circuits of more dangerous voltages should be kept entirely separate from those feeding the usual low-voltage circuits for consumers.

**284. 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.

## 3. NOTES ON THE RULES FOR ELECTRICAL UTILIZATION EQUIPMENT

### SCOPE OF THE RULES

In workshops, mercantile establishments, and similar places more reliance must be placed on the physical guarding of live parts of electrical utilization equipment and less on care of operators than is the case with station or line equipment. No live parts should be left exposed to chance contact if the voltage exceeds a moderate limit. Where, however, utilization equipment is placed in separate rooms to which none but qualified

persons have access the balance between guards and operating precautions becomes about the same as in Stations, and the less rigid construction requirements of Stations are made to apply. See also note on scope of rules for Stations.

**300. General Requirement.**

(*a*) The general requirement for adequate and suitable equipment is similar to the corresponding requirement in the British factory rules, and is paralleled by similar requirements under the parts on Stations and Lines. See notes 100 and 200.

(*b*) These rules are met by standard electrical apparatus and hence, generally speaking, no extra expense is involved in the observance of the rules.

**301. Inspection.**

See note 111 Stations.

**302. Grounding.**

(*a*) See note 113 (*a*) Stations.

(*b*) The grounding of circuits as a protective measure is entirely for the purpose of preventing persons or insulation being subjected to a voltage higher than the normal voltage of the circuit for which it is insulated and guarded. All circuits which can have their voltage increased by neighboring circuits through transformers, by contacts in overhead lines, or by electromagnetic or electrostatic induction, should be either recognized and guarded as of this higher voltage or should be so grounded that a dangerous voltage can not be imposed on them.

In the case of two-wire direct-current circuits grounding one side may cause electrolytic damage, and hence the grounding of such circuits is not required. Direct current railway circuits are so grounded, but not from safety considerations, and the electrolytic damage due to such circuits is usually very much greater than would be caused by two-wire lighting circuits even if the latter were grounded.

Circuits above 150 volts may give serious shocks even if grounded at one side, but if encased in grounded metal conduit or other inclosure danger from the normal voltage and also from leakage from any higher voltage circuits is avoided. Operating conditions frequently recommend the absence of grounds from such circuits. Three-wire circuits, however, should usually be grounded at the neutral, to prevent the increased hazards caused by the chance grounding of an outer wire.

(*c*) See note 113*b*–*c*–Stations.

**303. Working Space About Electrical Equipment.**

Crowded machinery with either live or moving parts gives the most hazardous condition in workshops. With restricted working space and

inconvenient access, equipment is liable to suffer from inattention, insufficient cleaning, and consequent more rapid deterioration to a condition endangering the attendant.

The installation of electrical utilization equipment after the plant has been built and other machinery set will frequently require such an amount of crowding as may produce unsafe conditions if some positive minimum working distances are not strictly adhered to. The distances mentioned in the rule may be too small where there is much moving apparatus or where there is equipment which may act suddenly. For instance, the opening of a circuit breaker or a fuse may cause the attendant to step backward into some other dangerous equipment. Where moving machinery must be placed close to working spaces, barriers which will effectively guard the parts are often used.

**304. Guarding or Isolating Live Parts.**

If live parts could always be perfectly guarded when persons are near them, shocks and burns from electrical causes would cease. With electrical utilization equipment this guarding is the more necessary, since the attention of employees must be given to the processes rather than to the electrical machinery.

Much utilization equipment can not be elevated beyond reach, but must be placed for convenience where unskilled persons may approach it. Elevation too, is of less value than in stations, depending on the character of materials handled and other circumstances. In some shops the handling of pipes or rods makes even a considerable elevation ineffective. Eight feet is named as about the greatest height to which the average person can raise his hands without standing on chair or other support.

The character of workmen and of processes makes insulating platforms less reliable than in dry stations free from other processes.

Complete inclosures for live parts provide the most satisfactory protection, since they prevent chance short circuits by tools or conducting materials in the hands of workmen, and where this is not feasible, efficient barrier guards may be used. When insulating platforms must be depended upon, they should be suitable for the conditions.

**305. In Hazardous Locations.**

Among locations where special inclosing of live parts of electrical equipment is necessary might be mentioned fertilizer plants, breweries, flour mills, gas works, dry-cleaning establishments.

**306. Storage Batteries, Transformers, and Lightning Arresters.**

The lightning arrester on overhead electrical lines has been found in a large proportion of cases to be a dependable device for preventing damage

from lightning discharges. It must not be inferred that lightning arresters may not be desirable where the run of the overhead conductors is less than 1000 feet. Frequently the use of lightning arresters on much shorter overhead lines, especially with yard distribution systems, may be desirable in exposed locations.

**307. Identifications.**

The ability to readily identify and trace the connections of equipment not only facilitates repairs but safeguards against danger of handling live parts in mistaken belief that they are disconnected. The rules of many commissions and countries dwell on this point. In the installation rules of the Verband Deutscher Elektrotechniker very complete diagrams are required to be kept in convenient locations to assist the other means for identification, and labels are specifically called for at automatic cutouts.

**310. Protection in General.**

(*a*) 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 sheath may be necessary for conductors with insulating covering.

For the best protection of persons in the vicinity, or engaged in operating switches on circuits, the 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.

Neutral conductors should not be interrupted unless outer conductors are broken at the same time. Such interruption has frequently resulted in unbalancing of load and the subjection of equipment and persons to nearly double the designed voltage. If a fuse is inserted in the grounded conductor ahead of the point where the ground wire is connected, the blowing of this fuse will permit the entire circuit to lose its ground connection and to assume the voltage and hazard of any circuit by which exposed.

(*b*) See note 150*b*, Stations.

**311. Isolating or Inclosing.**

While the isolation of insulated conductors is sometimes a satisfactory protection to persons, with higher voltages the hazard becomes greater and with some processes even the lower voltage conductors need inclosing guards.

**312. Guarding Conductors Over 150 Volts.**

(*a*) For conductors above 150 volts to ground, conduit protection is usually advisable, and the long life of such construction by aiding the

safety to persons and property is making this form of protection increasingly popular.

(*b*) Conductors brought near the floor line must be considered as more or less subject to contact and so endangering persons, unless permanent screens or similar guards are provided. If such guards are to be occasionally passed by, the use of insulating mats and covers may prevent persons from touching the conductors and grounded floors or machinery at the same time.

**313. Guarding in Hazardous Locations.**

(*a*) See note 153*a*, Stations.

(*b*) See note 153*b*, Stations.

**314. Portables and Pendants.**

Use of flexible conductors seems to be necessary to the convenience of electrical service, but this is one of the most frequent causes of electrical injuries and fires. Insulation is necessarily subjected to bending and abrasion when the conductors are being handled, and portable devices may be carried everywhere, regardless of plumbing or machinery in the vicinity. The necessity, therefore, for confining their use to the lowest voltages is apparent.

**315. 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 existing equipments. Such temporary wiring often remains for years, offering more or less menace to service and to operators, whereas the additional cost and time required to make the installation substantial would have been inconsiderable.

**317. Guarding Service Conduit.**

(*a*) Service conduits from overhead are subject to occasional leakage from contained conductors, due to breakdowns in electrical storms. While considered better protected if grounded, the isolation of 8 feet from accessible ground or floor is considered to provide reasonable safety with ungrounded service conduits. Underground service conduits are usually grounded and frequently contain grounded metal-sheathed cable.

(*b*) If conduit containing the service conductors outside of service cutouts is not separately and effectively grounded, it should not be allowed to be in contact with metal of inside conduits or with metal parts of the building. Cases have occurred where metal siding of the building or metal awning frames have been raised to a dangerous potential by such contacts, and where small ground connections to conduit within buildings have been burned off, leaving the entire conduit system alive.

**321. Hazardous Location.**

See note 161, Stations.

**322. Where Switches Are Required.**

See note 162, Stations.

**323. Character of Switches.**

(*b*) The protection of workmen is greatly promoted by arrangement for preventing circuits and equipment from being started while work is being done on them.

(*c*) Small switches and single pole switches of larger capacity frequently cause burns by failing to entirely close and arcing at the contacts near the hand of the operator.

**324. Disconnection of Fuses Before Handling.**

Except for fuses at low voltages, the danger of shock in removing them from exposed live clips or other contacts is considerable. With fairly large fuses, even at low voltages, the danger of receiving burns while replacing the fuse in a live clip, through blowing of the fuse by short circuits beyond it, is a serious one.

Many persons are annually burned by replacing fuses in live terminals, or by sudden blowing of fuses or circuit breakers near them.

Many cutout boxes and cabinets are being marketed in which the fuses are entirely disconnected from the source of energy supply before they become accessible.

Where such devices are not provided, a switch should be inserted in series with the fuses and between the fuses and the source of energy, and the fuses should be in locked cabinets or inclosures to prevent contact of thoughtless persons.

**325. Arcing or Suddenly Moving Parts.**

(*a*) Usually circuit breakers and fuses can be placed in cabinets or at such an elevation that persons are not subject to injury by arcing during their operation.

(*b*) In some cases operators have been severely injured by being struck by levers and handles of circuit breakers.

**326. Grounding Noncurrent Carrying Metal Parts.**

It is intended that the important exposed metallic parts of switches are to 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 Cutouts.**

See note 168, Stations.

**331. Convenient and Safe Attendance.**

See note 171, Stations.

**332. Safe Location.**

The practice of placing a switchboard directly in front of other live or moving parts is to be discouraged. Indeed, the operations about a switchboard are usually of such a character that as much freedom of action for the operator should be provided as the conditions will permit.

**337. Guarding Live Parts.**

(*a*) Where switchboards would otherwise have a multiplicity of live contacts and numerous operations must be frequently performed, it is often desirable to use the so-called "dead front" boards which manufacturers are now prepared to supply. Remote control is also frequently used in alternating current high-voltage construction.

Insulating floors have few of the disadvantages of unevenness and unreliability which mats and platforms possess, and in the dry clean surroundings usual with switchboards afford effective protection to the operator touching only one live part. Various materials, such as albarene stone, soapstone, slate, marble, are satisfactory. For insulating mats or platforms a depressed section of floor is advisable, so that their edges are flush with the floor surface itself.

(*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 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 exposed bare rod is made 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 depth of both contacts behind the board is sufficient so 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 the cable itself may break down and the person be injured by shock or burn from the conductors within.

**340. Control Devices.**

(*a*) The importance of automatic speed-limiting devices for certain types of motors and rotary converters should be better realized. More

cases of bursting rotating parts from overspeed occur than of boiler explosions, which are so seriously regarded. Direct current generators and rotary converters provide loads of a character which may become nearly zero by the opening of automatic cutouts, and if the field is weak the speed may be greatly accelerated.

Separately excited motors are particularly liable to "run away," since their excitation may be entirely lost while the armature current still is maintained. Centrifugal devices operating relays, which in turn actuate switches in the motor-supply circuits, are most often utilized as means of protection.

(*b*) One of the first principles which the operator learns about starting direct current motors is to have assurance that the motor will be energized with a suitable field. It frequently happens that a constant-speed motor is installed and later for some reason, as in the case of a machine tool application or a fan, it becomes necessary to secure a somewhat different speed by the use of field control. Care should be exercised that the control devices be so chosen that some relay, no voltage release attachment, or other means be provided to bridge the resistance and provide an effective means of preventing the starting of the motor with dangerously weakened field.

The no-voltage release coils on starters for direct current motors are frequently arranged so that they form a part of the field circuit of the motor. If the field opens or loses voltage through any reason, the starter is released and the motor is brought to the starting position. There will not be many cases where this practice can not be observed. It is good practice to interrupt the continuity of the magnetic circuits of such releases, so that they will not be retained by the residual magnetism between the keeper and the poles of the release magnet. Nonmagnetic metal strips are frequently placed in the air gap for this purpose.

(*c*) The relative importance of control circuits, together with the natural frailty of the comparatively small conductors employed, make the use of conduit essential to assure reliability.

The use of closed circuits permits readier and simpler control of the stopping devices, and any chance open circuit gives evidence by lamp or bell connected in the circuit. With open circuits, a break in the circuit may not be discovered until in emergency the control may be found inoperative. In some cases, such as motor-controlled switches or valves, open-circuit control must, however, be employed and the circuit must depend on careful protection to maintain it in operative condition.

**341. Hazardous Locations.**

An explosion-proof case has been defined as such inclosing covers or cases as will prevent the communication of a flame inside the cases to any

inflammable gases or flyings outside. It is frequently considered good practice to place motors in separate rooms or inclosures not subject to these bad conditions.

Iron conduit containing the wires can be screwed into the case of the starting rheostat and motor and the difficulty from the dust or gas largely eliminated.

**342. Deteriorating Agencies.**

Any hastening of deterioration by moisture, oil, or uncleanliness means danger of breakdown, which may occur while attendant is exposed. The insulation may also fail at the point where the attendant is handling it and cause harmful shock. The conditions of good contact and cramped surroundings are also likely to augment the danger under such circumstances.

**343. Guards for Live Parts.**

(*a*) For low-voltage machines the guarding is usually sufficient if it prevents touching live parts while standing on grounded parts. Insulated mats provide this protection. The most serious shocks are those where contacts are made so that the current passes through the entire body. For higher voltages the somewhat less frequent shocks incurred by touching live parts while the other hand or some part of the arm is against grounded parts must also be prevented by use of suitable inclosing or barrier guards about the live parts.

Suitable guards for live parts may be parts of machine frames or cases, or may be insulated handrails, preventing inadvertent contact with live parts.

(*b*) In some cases screens or other shields adjacent to the grounded frame, or other grounded parts which would be otherwise exposed to contact, will be advisable to protect persons who may necessarily be engaged in adjustment of brushes, commutators, or other live parts.

See note under 124*b*, Stations.

**350. Arc Furnaces.**

The shielding of the eyes and unclothed body surfaces from the radiation of any arcing process is quite essential and usually recognized, although 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 very similar to those caused by the sun. The injuries are usually much more severe by reason of the greater intensity. Much has been done by individual firms toward the solution of a proper system of colored glass to protect the eyes, and it is not infrequent that a combination of glass is used, some to cut down the intensity and others the ultra

violet or infra-red rays. The use of a suitable headgear is generally necessary. This often consists of a metallic covering fitting over the head, with openings in front of the eyes fitted with glass, as above described. Some provision for ventilation is also provided.

To prevent curious or unauthorized persons from injury by trespassing, 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 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 must be also grounded. This is usually carried out in practice by grounding both the exposed metal framework of the furnace or welder and any low voltage heating element which must be handled or moved about.

Frequently, insulating floors are impracticable from the nature of the processes or surroundings, and grounding must be depended upon to adequately minimize the shock hazard to which the worker may be subjected.

**352. Guarding Live Parts.**

In most electric furnaces live parts not held close to ground potential 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 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.

**360. Grounding.**

It is usually quite practicable to place lighting fixtures and other fixed electrical devices such as heaters, cash registers, etc., where no grounded surfaces (plumbing, machines, damp floors) are within reach. This is especially desirable when surrounding atmosphere is damp, as in baths, laundries, stables, breweries, packing plants. Fixtures may be placed on ceilings frequently with advantage to convenience and illumination alike. If, however, fixtures must be placed within reach from grounded surfaces, the grounding of the fixture itself becomes advisable.

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 recommended, but may in some cases be

inadvisable, as introducing different voltages at different points in the building which may in turn produce currents in unexpected and dangerous locations. The grounding of fixtures in this manner seems quite practicable, however, when the fixture is not in contact or close proximity with metal ceiling, metal lath, gas piping, metal reinforcement of building, 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.

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 be discouraged. The grounding of fixtures not insulated from gas piping, by means of a circuit conductor necessarily having a potential drop, is generally considered inadvisable.

Combination fixtures should be avoided wherever possible, from both life and fire hazard viewpoints.

**361. Insulation.**

In the past, one defect of fixtures has been their inability in actual service to withstand 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.

**362. Exposed Conductors and Live Parts.**

Many shocks have resulted from the exposure of live parts where the ordinary public has access, and such a hazard is greater where near much metallic piping or plumbing liable to be grounded. Frequent crosses and slight grounding of electrical circuits at other places makes it possible to establish a circuit at such points. In some instances ordinary lighting circuit voltages are sufficient to cause death.

By identifying conductors, as is thoroughly practicable, and now done in Providence, R. I., it becomes easy to fix the screw shell of sockets and receptacles at ground potential, reducing the probability of breakdown to external metal of the socket, and preventing danger from per-

sons touching the ungrounded screw lamp base and at the same time the grounded outer casing.

**364. Control of Outdoor Signs.**

The use of a switch within sight of a sign is advisable. The possibility of some other person closing the circuit is present and the workman on a grounded structure, such as a sign usually is, will be subjected to shock. Even a slight shock is dangerous to persons in elevated positions. The person can provide some protection for himself, if the switch is where he can see it.

**365. Connectors of Signs.**

Manufacturers are now making connectors where the live parts are protected against contact by being provided with insulating shields covering otherwise exposed parts. These have also frequent application in other exposed locations, as, for instance, in garages where electric vehicle batteries are charged.

**366. Isolating or Guarding Lamps in Series Circuits.**

Series circuits are very objectionable in buildings or in spaces accessible to the general public. Even on poles out of ordinary reach high voltages may expose curious persons or children, and the severity of shocks warrants much more care than is necessary with parts of lower voltages such as are common with constant voltage systems for interior wiring.

**370. Insulation.**

In most portable devices now in use, 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 temperatures are not too high, but is not satisfactory in damp locations. Mica is suitable where there is much heat, as in an electric iron. In some instances, a suitable material must be developed. The possibilities of unusual conditions developed by overloading present many difficult problems for the designer who 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 advisable. 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 sometimes also used for carrying current to the device, but preferably used only for the protective purpose.

Because of the greater difficulties involved than in grounding fixtures, and because of the inadequate supply available of portable cord suitable for accomplishing the grounding, it has been deemed for the present advisable to require the grounding only for portables on circuits over 150 volts to ground, where the life hazard is so greatly increased over that with lower voltages that even the present difficulty in securing suitable cord is warranted.

**372. Cable Connectors.**

**373. Identified Conductors and Connectors.**

Where portable cable must be depended upon to ground external metal of portable devices, the connectors must be of a type such that no connection of live 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 plugs in practical use of the device. The employment of a separate ground wire (a third wire with two conductor cables) makes very unlikely the mistakes which might presumably occur if one of the two circuit wires is utilized as ground wire for the portable device.

**374. Use of Portables and Pendants.**

Many engineers are averse to 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 have become very unsafe by lack of insulation.

Limitations for their use are difficult to set since they offer the great advantage of convenience and at low voltages do not necessarily present serious life hazard. The rule indicates the caution 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.

**380. Guarding Live and Moving Parts—General Requirement.**

The number of injuries to motormen, conductors, and even the public by contact with exposed live parts or ungrounded (and accidentally

alive) metal frames is very considerable. Railway companies are adopting very thorough guarding and grounding measures to obviate these hazards. Elevator cages, cables, and shop locomotives present 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 receiving more attention than formerly.

**382. Control of Energy Supply.**

Some means of cutting off energy supply from cars is very essential. Removal of the trolley pole or pantograph from the trolley wire is usually possible under load, but removal of third-rail shoes under like condition is frequently impossible.

**390. Grounding Noncurrent Carrying Parts.**

The number of injuries to persons using telephones, fire-alarm boxes, and other devices in damp places has been considerable, because of the common failure to prevent a voltage between external metal parts of such devices and the ground or grounded floors on which the persons must stand. The grounding of fire and police alarm boxes and accessible metal parts is now almost universally supported, but is neglected in many places from a fear that the dielectric between current carrying parts within and the case will not withstand the strains from the voltages to which it is subjected. Such a weakness should evidently not be made a basis for permitting a condition by which high voltage may exist on external metal to which persons have access.

**392. Insulating Booths.**

The use of communication circuits parallel to supply circuits or otherwise exposed by them is unavoidable with the network of overhead lines commonly employed in every city and in many rural districts. The strength of construction may be depended upon, generally to prevent actual contacts, but actual separation must be relied upon to minimize electromagnetic and electrostatic influences, and to eliminate dangerous voltages on exposed signal lines from these sources.

One-to-one transformers have a limited use for separating the accessible signal circuit from that exposed. The best way is to prevent the exposure, and while no empiric table of voltages and distances can entirely guarantee the safety of exposed signal lines, it is believed that the table given will, for average heights and relative positions of signal lines, indicate reasonable exposures which should not be exceeded without observance of the special precautions named.

[Continued from page 2 of cover.]

47. Units of Weight and Measure; Definitions and Tables of Equivalents.
48. Standard Methods of Gas Testing.
49. Safety Rules to be Observed in the Operation of Electrical Equipment and Lines.
50. National Standard Hose Couplings and Fittings for Public Fire Service.
51. Measurement of Time and Tests of Timepieces.
52. Regulation of Electrotyping Solutions.
53. The Composition, Properties, and Testing of Printing Inks.
54. Proposed National Electrical Safety Code.