U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATION LINES
SAFETY RULES AND DISCUSSION

NATIONAL BUREAU OF STANDARDS HANDBOOK H43

U. S. DEPARTMENT OF COMMERCE
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National Bureau of Standards Handbook H43

INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATION LINES SAFETY RULES AND DISCUSSION

Comprising Part 2, the Discussion of Part 2, the Definitions, and the Grounding Rules of the Fifth Edition of the National Electrical Safety Code

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PREFACE

This Handbook contains definitions, grounding rules, and Part 2 of the fifth edition of the National Electrical Safety Code dealing with the construction and maintenance of overhead and underground lines, originally published as Handbook H32, together with a discussion of the grounding rules and of Part 2 of the code published as Handbook H39.

In addition to the discussion of code requirements, this Handbook includes the three appendices which contain certain technical data that will be found useful in making computations of the strengths of supporting structures and in determining crossing clearances. In some cases there are suggested engineering short cuts which give approximately the same results as formulas covered in the code.

The printing of this Handbook serves to combine in one binding the code rules on lines with related engineering data and useful information. An index has been added to assist in locating rules and the discussion thereof.

As tables are used in this discussion as well as in the code, and as reference is frequently made to code tables in the discussion, some method of identifying the source seemed desirable. Consequently, it has been decided to add a prefix "D" to all table numbers included in the discussion; thus table 4 will be found in H32 (the code), but table D4 will be found in the discussion. As the only figures used in H32 are those of "Conductor Conflict" and "Structure Conflict" in section 1, and as these are not numbered, no such identification of figures is necessary.

This discussion was prepared by a representative Handbook Discussion Committee appointed, during one of the meetings of the Sectional Committee, by its late chairman,

M. G. Lloyd. Other members of the Sectional Committee were called on when the discussion of certain rules with which they were particularly conversant was being considered. Engineers representing certain wire manufacturers assisted in the preparation of sections dealing with sags and tensions. Their assistance is gratefully acknowledged.

It is not the intent of this discussion to modify the requirements of any of the rules discussed, and if there appears to be any discrepancy, the rule as stated in the code governs.

Comments from engineers familiar with overhead and underground lines are invited, so that future editions may be more nearly complete and consequently more valuable to users of the code.

The system of page identification used in Handbook H30 has also been used in this Handbook. The page numbers of Handbooks H32 and H39 have been retained in the caption on the binding edge of each page. This permits easy and positive identification of material in correspondence, regardless of the Handbook used to locate the material in question.

E. U. Condon, *Director.*

CONTENTS

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SAFETY RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATION LINES

SEC. 1. DEFINITIONS OF SPECIAL TERMS

Alphabetical List of Defined Terms

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

2. **Appliance** means current-consuming equipment, fixed or portable; for example, heating, cooking, and small motor-operated equipment.

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

4. **Cable vault.** (See definition of "Manhole.")

5. **Circuit** means a conductor or system of conductors through which an electric current is intended to flow.

6. **Circuit-breaker** means a device designed to open under abnormal conditions a current-carrying circuit without injury to itself. The term as used in this code applies only to the automatic type designed to trip on a predetermined overload of current.

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

8. **Common use** means simultaneous use by two or more utilities of the same kind.

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

10. **Grounding conductor** means a conductor which is used to connect the equipment or the wiring system with a grounding electrode or electrodes.

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

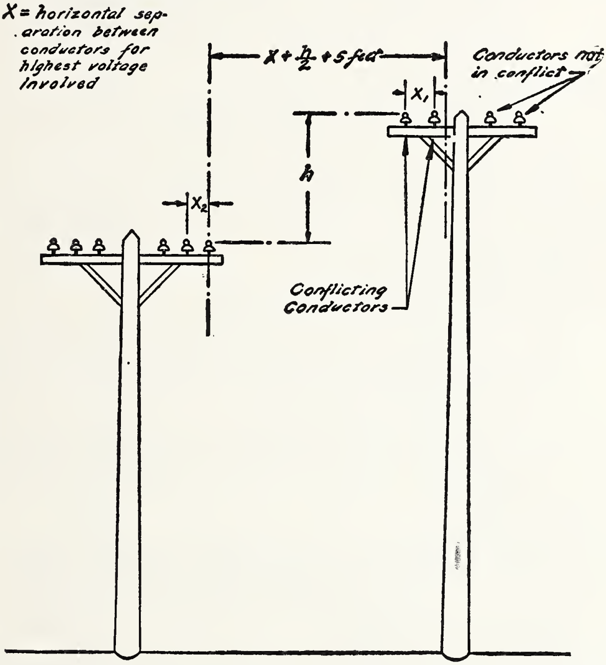
12. **Line conductor** means one of the wires or cables carrying electric current, supported by poles, towers, or

other structures, but not including vertical or lateral connecting wires.

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

Conflict:

14. Antenna conflict means that an antenna or its guy wire is at a higher level than a supply or communication



Conductor Conflict

conductor and approximately parallel thereto, provided the breaking of the antenna or its support will be likely to result in contact between the antenna or guy wire and the supply or communication conductor.

15. Conductor conflict means that a conductor is so

situated with respect to a conductor of another line at a lower level that the horizontal distance between them is less than the sum of the following values:

(a) Five feet.

(b) One-half the difference of level between the conductors concerned.

(c) The value required in tables 6, 7, or 8 for horizontal separation between conductors on the same support for the highest voltage carried by either conductor concerned. (See illustration.)

16. **Structure conflict** (as applied to a pole line) means that the line is so situated with respect to a second line that the overturning (at the ground line) of the first line will result in contact between its poles or conductors and the conductors of the second line, assuming that no conductors are broken in either line. (See illustration.)

Exceptions: Lines are not considered as conflicting under the following conditions:

(1) Where one line crosses another.

(2) Where two lines are on opposite sides of a highway, street, or alley and are separated by a distance not less than 60 percent of the height of the taller pole line and not less than 20 feet.

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

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

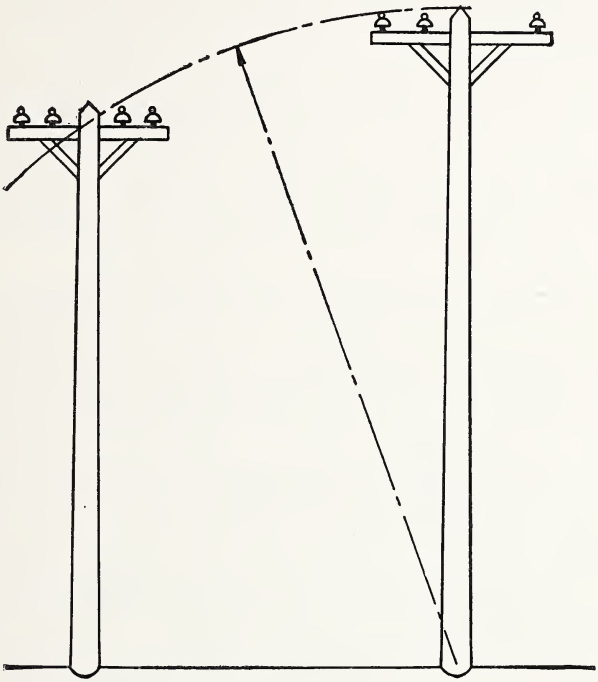
19. **Device** means a unit of an electric wiring system which is intended to carry but not consume electric energy.

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

Note: 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.

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

22. **Electric fence** means a barrier to animals or fowls,



Structure Conflict

consisting of an electrified conductor energized through an electric-fence controller.

23. **Electric-fence wire** means any electrified conductor, such as a wire, ribbon, tape, rod, tube, plate, mesh, or any other form suitable for, and used as, a barrier to animals or fowls.

24. **Electrical supply station** means any building, room, or separate space within which electric-supply equipment is

located and the interior of which is accessible, as a rule, only to properly qualified persons.

Note: This includes generating stations and substations and generator, storage-battery, and transformer rooms, but excludes manholes and isolated-transformer vaults on private premises. (See definition of "transformer vault".)

25. **Equipment** means a general term including fittings, devices, appliances, fixtures, apparatus, and the like, used as a part of, or in connection with, an electric installation.

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

(a) Where the voltage does not exceed 150.

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

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

28. **Explosion-proof** means capable of withstanding without injury and without transmitting flame to the outside any explosion of gas which may occur within.

Exposed:

29. **Applied to circuits or lines** means in such a position that in case of failure of supports or insulation contact with another circuit or line may result.

30. **Applied to equipment** means that an object or device can be inadvertently touched or approached nearer than a safe distance by any person. It is applied to objects not suitably guarded or isolated.

31. **Externally operable** means capable of being operated without exposing the operator to contact with live parts.

Note: This term is applied to equipment, such as a switch, that is inclosed in a case or cabinet.

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

33. **Effectively grounded** means permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient current-carrying capacity to prevent the building up of voltages which may result in undue hazard to connected equipment or to persons.

34. **Grounded system** means a system of conductors in which at least one conductor or point (usually the middle wire, or neutral point of transformer or generator windings) is intentionally grounded, either solidly or through a current-limiting device.

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

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

37. **Inclosed** means surrounded by a case which will prevent accidental contact of a person with live parts. A solid inclosure means one which will neither admit accumulations of flyings or dust, nor transmit sparks or flying particles to the accumulations outside.

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

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

39. **Insulating** (where applied to the covering of a conductor, or to clothing, guards, rods, and other safety devices) means that a device, when interposed between a person and current-carrying parts, protects the person making use of it against electric shock from the current-carrying parts with which the device is intended to be used; the opposite of conducting.

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

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

42. **Joint use** means simultaneous use by two or more kinds of utilities.

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

44. **Lightning arrester** means a device which has the property of reducing the voltage of a surge applied to its terminals, is capable of interrupting follow current if present, and restores itself to its original operating conditions.

Lines:

45. **Communication lines** means the conductors and their supporting or containing structures which are located outside of buildings and are used for public or private signal or communication service, and which operate at not exceeding 400 volts to ground or 750 volts between any two points of the circuit, and the transmitted power of which does not exceed 150 watts. When operating at less than 150 volts no limit is placed on the capacity of the system.

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

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

Exception is made under certain conditions for communication circuits used in the operation of supply lines. (See rule 288, A).

46. **Minor communication lines** means communication lines carrying not more than two circuits used mainly for local telephone or telegraph service, or for police or fire-alarm service.

47. **Electric-supply lines** means those conductors and their necessary supporting or containing structures which are located entirely outside of buildings and are used for transmitting a supply of electric energy.

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

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

48. **Low-voltage protection** means the effect of a device operative on the reduction or failure of voltage to cause and maintain the interruption of power supply to the equipment protected.

49. **Low-voltage release** means the effect of a device operative on the reduction or failure of voltage to cause the interruption of power supply to the equipment, but not preventing the reestablishment of the power supply on return of voltage.

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

51. **Manual** means capable of being operated by personal intervention.

52. **Minor tracks** means railway tracks included in the following list:

(a) Spurs less than 2,000 feet long and not exceeding two tracks in the same span.

(b) Branches on which no regular service is maintained or which are not operated during the winter season.

(c) Narrow-gage tracks or other tracks on which standard rolling stock can not, for physical reasons, be operated.

(d) Tracks used only temporarily for a period not exceeding 1 year.

(e) Tracks not operated as a public utility, such as industrial railways used in logging, mining, etc.

53. **Open wire** means a conductor or pair of conductors separately supported above the surface of the ground.

54. **Panelboard** means a single panel, or a group of panel units designed for assembly in the form of a single panel, including buses and with or without switches and/or automatic overcurrent-protective devices for the control of light, heat, or power circuits of small individual as well as aggre-

gate capacity; designed to be placed in a cabinet or cut-out box placed in or against a wall or partition, and accessible only from the front. (See definition of "Switchboard.")

55. **Qualified** means familiar with the construction and operation of the apparatus and the hazards involved.

56. **Raceway** means any channel for loosely holding wires or cables in interior work, which is designed expressly and used solely for this purpose. Raceways may be of metal, wood, or insulating material, and the term includes wood and metal moldings consisting of a backing and capping, and also metal ducts into which wires are to be pulled.

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

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

Sag:

59. **Apparent sag at any point** means the departure of the wire at the particular point in the span from the straight line between the two points of support of the span, at 60° F, with no wind loading.

60. **Apparent sag of a span** means the maximum departure of the wire in a given span from the straight line between the two points of support of the span, at 60° F, with no wind loading.

61. **Final unloaded sag** means the sag of a conductor after it has been subjected for an appreciable period to the loading prescribed for the loading district in which it is situated, or equivalent loading, and the loading removed.

62. **Initial unloaded sag** means the sag of a conductor prior to the application of any external load.

63. **Maximum total sag** means the total sag at the midpoint of the straight line joining the two points of support of the conductor.

64. **Total sag** means the distance measured vertically from any point of a conductor to the straight line joining its two points of support, under conditions of ice loading equivalent to the total resultant loading for the district in which it is located.

65. **Unloaded sag of a conductor at any point in a span** means the distance measured vertically from the parti-

cular point in the conductor to a straight line between its two points of support, without any external load.

66. **Service** means the conductors and equipment for delivering electric energy from the secondary distribution or street main, or other distribution feeder, or from the transformer, to the wiring system of the premises served. For overhead circuits, it includes the conductors from the last line pole to the service switch or fuse. The portion of an overhead service between the pole and building is designated as "service drop."

67. **Span length** means the horizontal distance between two adjacent supporting points of a conductor.

68. **Splicing chamber.** (See definition of "Manhole.")

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

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

71. **Switchboard** means a large single panel, frame, or assembly of panels, on which are mounted (on the face, or back, or both) switches, fuses busses, and usually instruments.

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

Tension:

73. **Final unloaded conductor tension** means the longitudinal tension in a conductor after the conductor has been stretched by the application for an appreciable period, and subsequent release, of the loadings of ice and wind, and temperature decrease, assumed for the loading district in which the conductor is strung (or equivalent loading).

74. **Initial conductor tension** means the longitudinal tension in a conductor prior to the application of any external load.

75. **Transformer vault** means an isolated inclosure either above or below ground with fire-resistant walls, ceiling, and floor, in which transformers and related equipment are

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installed, and which is not continuously attended during operation.

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

Voltage:

77. **Voltage of a circuit** means the highest effective voltage between any two conductors of the circuit concerned.

Exception: Voltage of a grounded multiwire circuit, not exceeding 750 volts between any two conductors, means the highest effective voltage between any wire of the circuit and that point or conductor of the circuit which is grounded.

If one circuit is directly connected to another circuit of higher voltage (as in the case of an autotransformer), both are considered as of the higher voltage, unless the circuit of lower voltage is effectively grounded, in which case its voltage is not determined by the circuit of higher voltage. Direct connection implies electric connection as distinguished from connection merely through electromagnetic or electrostatic induction.

Voltage to ground of:

78. **A grounded circuit** means the highest effective voltage between any conductor of the circuit and that point or conductor of the circuit which is grounded.

79. **An ungrounded circuit** means the highest effective voltage between any two conductors of the circuit concerned.

Voltage to ground of a conductor of:

80. **A grounded circuit** means the highest effective voltage between such conductor and that point or conductor of the circuit which is grounded.

81. **An ungrounded circuit** means the highest effective voltage between such conductor and any other conductor of the circuit concerned.

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

SEC. 9. RULES COVERING METHODS OF PROTECTIVE GROUNDING OF OVERHEAD AND UNDERGROUND LINES AND RELATED EQUIPMENT

CONTENTS

90. Scope of the Rules.

The following rules apply to the grounding of all lightning arresters except those on communication circuits, and of all circuits, equipment, or wire raceways when the grounding is intended to be a permanent and effective protective measure.

They do not apply to the grounded return of electric railways, nor to the grounding of lightning protection wires which are independent of electric circuits or equipment. These rules do not require that grounding shall be done, but cover the methods for protective grounding. The rules requiring grounding, in accordance with the methods specified below, are included under the various parts of this code.

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

91. Application of the Rules.

A. Waiving Rules.

The rules are intended to apply to all installations except as modified or waived by the proper administrative authority or its authorized agents. They are intended to be so modified or waived in particular cases wherever any rules are shown for any reason to be impracticable, such as by involving expense not justified by the protection secured; provided equivalent or safer construction is secured in other ways.

B. Application.

The intent of the rules will be realized (1) by applying the rules in full to all new installations, reconstructions, and extensions, except where any rule is shown to be impracticable for special reasons or where the advantage of uniformity with existing

91. B. Application—Continued.

construction is greater than the advantage of construction in compliance with the rules, provided the existing construction is reasonably safe; (2) by placing grounds on existing installations or bringing present grounds into compliance with the rules, except where the expense involved is not justifiable. The time allowed for bringing existing installations into compliance with the rules will be determined by the proper administrative authority.

C. Temporary Installations.

It will sometimes be necessary to modify or waive certain of the rules for specified limited periods of time in case of temporary installations or installations which are shortly to be dismantled or reconstructed.

D. Emergency.

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

92. Point of Attachment of Grounding Conductor.

A. Direct-Current Distribution Systems.

Direct-current systems which are to be grounded shall have the grounding connection made at one or more supply stations but not at individual services and not elsewhere on interior wiring. In three-wire direct-current systems the ground connections shall be made on the neutral.

B. Alternating-Current Distribution Systems.

In alternating-current systems the ground connection shall be made at the building service or near the transformer (or transformers) either by direct ground connection (through water-piping system or artificial ground, see rule 94) or by the use of a system ground wire to which are connected the grounded conductors of many secondary mains and which is itself effectually grounded at intervals that will fulfill, for any secondary utilizing the system

92. B. Alternating-Current Distribution Systems—Contd.

ground wire, the resistance and current-carrying requirements of these rules.

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

Alternating-current secondary circuits supplied from a transformer outside the building shall not be grounded inside buildings except at the service entrance.

In single-phase, three-wire systems the ground shall be on the neutral conductor. In two-wire single-phase and in two-or three-phase systems the ground shall be made at that point of the system which brings about the lowest voltage from ground of unguarded current-carrying parts of connected devices. Where one phase of a two- or three-phase system is used for lighting, that phase should be grounded and at the neutral conductor, if one is used.

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

C. Current in Grounding Conductor.

Grounds shall be so arranged that under normal conditions of service there will be no objectionable flow of current over the grounding conductor.

The temporary currents set up under accidental conditions, while the grounding conductors are performing their intended protective functions, are not to be considered as objectionable.

If an objectionable flow of current occurs over a grounding conductor, due to the use of multiple grounds, (1) one or more of such grounds shall be abandoned, or (2) their location shall be changed, 92\. C. Current in Grounding Conductor—Continued

or (3) the continuity of the conductor between the grounding connections shall be suitably interrupted, or (4) other means satisfactory to the administrative authority shall be taken to limit the current.

D. Equipment and Wire Raceways.

Metal boxes, cabinets and fittings, or non-current-carrying metal parts of other fixed equipment, if metallically connected to grounded cable armor or metal raceway, are considered to be grounded by such connection. Where the metal enclosure of a wiring system is used as part of the protective grounding, the electrical continuity of the enclosure shall be assured.

For conduit, armored cable, or metal raceways the ground connection shall be as near as practicable to the point where the conductors in the raceway system concerned receive their supply.

E. Service Conduit.

When the service conduit is grounded, its grounding wire shall be run directly from it to the ground connection. The interior conduit, armored cable, or metal raceways, if well bonded to the service conduit, grounded as provided in this rule, needs no additional ground connection.

93\. Grounding Conductor.

A. Material and Continuity.

In all cases the grounding conductor shall be of copper or of other metal which will not corrode excessively under the existing conditions and, if practicable, shall be without joint or splice. If joints are unavoidable they shall be so made and maintained as to conform to the resistance requirements of rule 96.

In no case shall a fuse or automatic circuit-breaker be inserted in the grounding conductor or connection except in a ground connection from equipment where its operation will result in the automatic disconnection from all sources of energy of the circuit leads

93. A. Material and Continuity—Continued.

connected to equipment so grounded; no switch shall be so inserted except in plain sight, provided with distinctive marking and effectively isolated from unqualified persons. (See also rule 92, B, par. 2.)

For lightning arresters and ground detectors the grounding conductor shall be as short and straight as practicable and free from sharp bends.

B. Size and Capacity.

The grounding conductor shall conform to the following:

1. FOR DIRECT-CURRENT CIRCUITS.

A grounding conductor for a direct-current supply system shall have a current-carrying capacity not less than that of the largest conductor supplied by the system and in no case less than that of No. 8 copper.

2. FOR ALTERNATING-CURRENT CIRCUITS.

A grounding conductor for an alternating-current system shall have a current-carrying capacity not less than one-fifth that of the conductor to which it is attached and in no case less than that of No. 8 copper.

3. FOR INSTRUMENT TRANSFORMERS.

The grounding conductor for instrument cases and secondary circuits of instrument transformers shall not be smaller than No. 12 if of copper or, if of other metal, shall have equivalent current-carrying capacity.

4. FOR LIGHTNING ARRESTERS.

The grounding conductor or conductors shall have a current capacity sufficient to insure continuity and continued effectiveness of the ground connection under conditions of excess current caused by or following discharge of the arrester. No individual grounding conductor shall have less conductance than No. 6 (0.162-inch) copper wire.

93. B. Size and Capacity—Continued.

5. FOR RACEWAYS AND EQUIPMENT.

The current-carrying capacity of grounding conductors for equipment, raceways, cable armor, and other metal enclosures for wires, when provided with overcurrent protection, shall be sufficient to provide adequate draining of fault current during the time required for the protective device to operate. Where connected to artificial electrodes, the grounding conductor need not be larger than No. 6 copper wire or its equivalent. If no fuse or automatic circuit-breaker is provided, the capacity of the grounding conductor shall be determined by the design and operating conditions of the circuit, but shall not be smaller than No. 8.

6. FOR PORTABLE AND PENDENT EQUIPMENT.

For grounding portable or pendent equipment, the conductors to which are protected by fuses or circuit-breakers rated or set at not exceeding 15 amperes, No. 18 copper wire may be used. For grounding portable or pendent equipment protected at more than 15 amperes, see preceding paragraph.

C. Mechanical Protection and Guarding Against Contact.

Where exposed to mechanical injury, the grounding conductor shall be protected by substantial conduit or other guard. Guards for lightning-arrester grounding conductors shall be of nonmagnetic material unless the grounding conductor is electrically connected to both ends of the guard.

If the resistance of the ground connection is in excess of three ohms, the grounding conductor, except in rural districts, shall be protected and guarded by being inclosed in insulating conduit or

93. C. Mechanical Protection and Guarding Against Contact.—Continued.

molding to protect persons from injury by coming in contact with it.

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

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

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

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

A grounding conductor for a circuit shall be guarded as required for current-carrying conductors of the circuit.

Exception 1: A grounding conductor for a circuit having at least two ground connections, where such conductor is entirely outside buildings and has strength and current capacity not less than No. 8 (0.1285-inch) copper wire.

Exception 2: In stations substantial bare ground busses may be used.

D. **Underground.**

Wires used for grounding conductors, if laid underground, shall, unless otherwise mechanically protected, be laid slack to prevent their being readily broken, and shall have joints carefully painted or otherwise protected against corrosion.

93. Grounding Conductor—Continued.

E. Common Grounding Conductor for Circuits, Metal Raceways, and Equipment.

The grounding conductor of an interior wiring system may be used also as the grounding conductor for equipment, conduit, and other metal raceways or enclosures for conductors, including service conduit or cable sheath and service equipment, provided such grounding conductor meets the current-carrying-capacity requirements for service raceways, as specified in paragraph B above; and provided further, that the secondary distribution circuit supplying the interior wiring system has at least one additional ground at the transformer or elsewhere.

94. Ground Connections.

The ground connection shall be permanent and effective, and be made as indicated below, but always to water-piping systems, if available.

A. Piping Systems.

For circuits, equipment, and arresters at supply stations, connections shall be made to all available active metallic underground water-piping systems between which no appreciable difference of potential normally exists, if the pipe is of sufficient capacity, and to one such system if appreciable differences of potential do exist between them. At other places connections shall be made to at least one such system, if available. Gas piping should be avoided for circuit grounding wherever practicable.

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

Ground connections from circuits should not be made to jointed piping within buildings except water piping.

94. Ground Connections—Continued.

B. Alternate Methods.

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

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

C. Artificial Grounds.

If resort must be had to artificial grounds, their number should be determined by the following requirements:

1. Not more than one such ground is required for lightning arresters, except where for large current capacity.
2. At least two grounds are required for low-voltage alternating-current distribution circuits at transformers or elsewhere, except as specified in 3.
3. Where no part of the circuit or equipment protected can be reached by persons while they are standing on the ground or damp floors, or by persons while touching any metallic piping to which the grounding conductor is not effectively connected, a single artificial ground may be used even if its resistance exceeds that specified in rule 96. In such cases it is desirable to provide guards for the grounding conductor in accordance with rule 93, C, wherever it is otherwise accessible, or to provide insulating mats or platforms so located

94. C. Artificial Grounds—Continued.

that persons can not readily touch the grounding conductors without standing on such mats or platforms.

D. **Grounds to Railway Returns.**

Protective ground connections should not be made to railway negative-return circuits when other effective means of grounding are available, except ground connections from electric-railway lightning arresters.

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

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

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

95. Method.

A. **Piping.**

The point of attachment of a grounding conductor to a water-piping system shall be on the street side of the water meter, or on a cold-water pipe of adequate current-carrying capacity, as near as practicable to the water-service entrance to the building or near the equipment to be grounded, and shall be accessible except by special permission. If the point of attachment is not on the street side of the water meter, the water-piping system shall be made electrically continuous by bonding together all parts between the attachment and the pipe entrance which

95. A. Piping—Continued.

are liable to become disconnected, as at meters and service unions. If water meters are located outside buildings or in concrete pits within buildings where piping connections are embedded in concrete flooring, the ground connections may be made on the building side of the meters.

Gas-piping systems within buildings shall not be used for purposes of this rule where water pipes are readily available. Gas piping may serve as the grounding electrode for fixtures located at a considerable distance from water piping. Where gas piping is so used it shall be bonded to the water-piping system at the point of entrance of water piping. (See rule 94, A.)

B. Ground Clamps.

The ground connection to metallic-piping systems shall be made by means of an approved clamp firmly bolted to the pipe after all rust and scale have been removed, or by means of a brass plug which has been tightly screwed into a pipe fitting or, where the pipe is of sufficient thickness, screwed into a hole in the pipe itself, or by other equivalent means.

The grounding conductor shall be attached to the clamp or to the plug by means of solder or by an approved solderless connector. The point of connection shall be as readily accessible as practicable.

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

C. Contact Surfaces.

If conduit, couplings, or fittings having protective coating of nonconducting material, such as enamel, are used, such coating shall be thoroughly removed from threads of both couplings and conduit and such surfaces of fittings where the conduit or ground clamp is secured, in order to obtain the requisite good connection. Grounded pipes shall be free from rust, scale, etc., at the place of attachment of ground clamp.

95. C. Contact Surfaces—Continued.

Conduits, other metal raceways, and the armor of cables shall be securely fastened in outlet boxes, junction boxes, and cabinets, so as to secure good electrical connection.

In ice houses, packing plants, etc., where a great deal of moisture is present and where conduits are attached to metal cabinets, cut-out, pull, or junction boxes, compensators, etc., by means of lock nuts and bushings, these conduits should be bonded together.

D. Electrodes for Artificial Grounds.

Where artificial grounds are used, the electrodes shall, as far as practicable, be embedded below permanent moisture level.

Buried-plate electrodes shall present not less than 2 square feet of surface to exterior soil. Electrodes of plate copper shall be at least 0.06 inch in thickness. Electrodes of iron or steel plates shall be at least ¼ inch in thickness.

Electrodes of iron or steel pipe shall be galvanized and not less than ½ inch (nominal size). Electrodes of rods of steel or iron shall be at least ¾ inch minimum cross-sectional dimension. Approved rods of nonferrous materials or their approved equivalent used for electrodes shall be not less than ½ inch in diameter. Driven electrodes of pipes or rods, if of less than standard commercial length, shall preferably be of one piece, and, except where rock bottom is encountered, shall be driven to a depth of at least 8 feet regardless of size or number of electrodes used. Such pipes or rods shall have clean metal surfaces and shall not be covered with paint, enamel, or other poorly conducting materials.

Pole-grounding electrodes may be wire attached to the pole previous to the setting of the pole. The wire shall have a continuous length below ground level of not less than 12 feet, shall extend to the bottom of the pole, and shall be not smaller than No. 6 (0.162 inch).

96. GROUND RESISTANCE.

A. Limits.

The combined resistances of the grounding wire and the connection with the ground shall not exceed 3 ohms for water-pipe connections nor 25 ohms for artificial (buried or driven) grounds. Where it is impracticable to obtain, with one electrode, artificial-ground resistance as low as 25 ohms, this requirement shall be waived, and two or more electrodes, at least 6 feet apart, shall be provided.

B. Checking.

The resistance of station grounds should be checked when made.

Note: With artificial grounds this check may be made by measuring the voltage between the grounded point of the circuit, or the grounded frame of the equipment, or the grounded point of the lightning arrester, and an auxiliary metal reference rod or pipe driven into the ground, while a measured current is flowing through the ground connection and any exposed metal piping or other artificial ground not less than 20 feet distant.

If the station ground is to water piping, the check may be made with current flowing through the water piping and some independent piping system or artificial ground not less than 20 feet distant.

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

All ground connections shall be inspected periodically. Ground connections on distribution circuits should, when installed, be tested for resistance unless multiple grounding is used.

97. SEPARATE GROUNDING CONDUCTORS AND GROUNDS.

A. Grounding Conductors.

Grounding conductors from equipment and circuits of each of the following classes, if required by these rules, shall be run separately to the ground or to a sufficiently heavy grounding bus or system ground cable which is well connected to ground at more than one place, except as provided in paragraph C and in rule 285, C.

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97. A. Grounding Conductors—Continued.

1. Lightning arresters.
2. Secondaries connected to low-voltage lighting or power circuits, except that if a secondary distribution system has multiple grounds, utilization equipment and wire enclosures may use the same grounding conductor.
3. Secondaries of current and potential instrument transformers having primary voltages of more than 750 volts, and cases of instruments on these secondaries.
4. Frames of direct-current railway equipment and of equipment operating in excess of 750 volts.
5. Frames of utilization equipment or wire raceways other than covered by item 4, except as provided in item 2.
6. Lightning rods.

B. Electrodes.

Where individual artificial grounds are used, separate grounding electrodes as well as separate grounding conductors shall be used. This does not prohibit the bonding together of these separate electrodes near the ground level.

C. Interconnection of Primary Arrester and Secondary Neutral.

1. SOLID INTERCONNECTION.

The grounding conductor of a lightning arrester protecting a transformer which supplies a secondary distribution system may be interconnected with the grounded conductor of such secondary distribution system, provided that in addition to the direct grounding connection at the arrester either:

(a) The secondary has elsewhere a grounding connection to a continuous metallic underground water piping system (except that in urban water-pipe areas where there are four water-pipe grounds

97. C. 1. Solid Interconnection—Continued.

in each mile of secondary and not less than four on any individual secondary, the direct grounding connection at the arrester may be omitted); or

(b) The secondary neutral (which may or may not be common with the primary neutral) has at least four ground connections in each mile of line in addition to a ground connection at each individual service, or

(c) Permission is obtained from the administrative authority for any other condition.

2. INTERCONNECTION THROUGH SPARK GAP.

Where the secondary is not grounded as in item 1, interconnection, if made, shall be through a spark gap having a 60-cycle breakdown voltage of at least twice the primary circuit voltage but not necessarily more than 15 kilovolts, and there shall be at least one other ground on the grounded conductor of the secondary that is at least 20 feet distant from the lightning-arrester grounding electrode.

PART 2. RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATION LINES

CONTENTS

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

200. Scope of Rules.

A. Extent of Application.

The following rules apply to electric supply and communication lines in overhead and underground construction whether operated in connection with public utilities, privately or municipally owned, with industrial establishments, or otherwise.

B. Not Complete Specifications.

These rules are not complete specifications but are intended to embody the requirements which are most important from the standpoint of safety to employees and the public.

C. Conformity with Good Practice.

Construction should be made according to accepted good practice for the given local conditions in all particulars not specified in the rules.

201. Application of the Rules and Exemptions.

A. Intent, Modification.

The rules shall apply to all installations except as modified or waived by the proper administrative authority. They are intended to be so modified or waived whenever they involve expense not justified by the protection secured or for any other reasons are impracticable; or whenever equivalent or safer construction can be more readily provided in other ways.

B. Realization of Intent.

The intent of the rules will be realized:

1. By applying the rules in full to all new installations, reconstructions, and extensions, except where for special reasons any rule is shown to be impracticable or where the advantage of uniformity with existing construction is greater than the advantage of construction in conformity with the rules.

201. **Realization of Intent**—Continued.

2. By placing guards on existing installations or otherwise bringing them into compliance with the rules, except where the expense involved is not justifiable.

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

C. Waiver for Temporary Installations.

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

D. Waiver in Emergencies.

In case of emergency or pending decision of the administrator, the person responsible for the installation may decide as to modification or waiver of any rule, subject to review by proper authority, but shall first notify all parties directly concerned in advance of construction.

202. Minimum Requirements.

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

Note: Some of these minimum values are exceeded in much existing construction; service requirements frequently call for stronger supports and higher factors of safety than the minimum requirements of these rules.

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

210. Design and Construction.

All electric supply and communication lines and equipment shall be of suitable design and construction for the service and conditions under which they are to be operated.

211. Installation and Maintenance.

All electric supply and communication lines and equipment shall be installed and maintained so as to reduce hazards to life as far as practicable.

212. Accessibility.

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

213. Inspection and Tests of Lines and Equipment.

A. When in Service.

1. INITIAL COMPLIANCE WITH RULES.

Lines and equipment shall comply with these safety rules upon being placed in service.

2. INSPECTION.

Lines and equipment shall be systematically inspected from time to time by the person responsible for the installation.

3. TESTS.

Lines and equipment shall be subjected, when necessary, to tests which will determine their fitness for service.

4. RECORD OF DEFECTS.

Any defects revealed by inspection, if not promptly corrected, shall be recorded.

5. REMEDYING DEFECTS.

Defective lines and equipment shall be put in good order or effectively disconnected.

B. When Out of Service.

1. LINES INFREQUENTLY USED.

Supply lines and equipment infrequently used shall be inspected to see that they are in safe condition for service.

213. B. When Out of Service—Continued.

2. LINES TEMPORARILY OUT OF SERVICE.

Lines temporarily out of service shall be maintained in such condition that a hazard will not be created.

3. LINES PERMANENTLY ABANDONED.

Lines permanently abandoned shall be removed or maintained in a safe condition.

Note: Overhead service drops to consumers are often disconnected without removal when the service is discontinued. This is considered good practice when it is undesirable to remove the service drop entirely.

214. Isolation and Guarding.

A. Current-carrying Parts.

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

B. Noncurrent-carrying Parts.

Ungrounded metal-sheathed service cables, service conduits, metal fixtures, and similar noncurrent-carrying parts, if located in urban districts and where liable to become charged to more than 300 volts to ground, shall be isolated or guarded so as not to be exposed to accidental contact by unauthorized persons.

As an alternative to isolation or guarding, grounding of certain noncurrent-carrying parts is permitted by rule 215, B, and rule 280, A, 4.

215. Grounding of Circuits and Equipment.

A. Methods.

The methods to be used for effective grounding for lightning arresters of supply lines, for circuits,

215. A. Methods.—Continued.

for equipment and for wire raceways are given in section 9. The methods to be used for grounding of lightning arresters of communication lines are specified in rule 392, part 3 of this code.

B. Parts to be Grounded.

In urban districts metal conduits, cable sheaths, metal lamp posts, and frames, cases, and hangers of equipment shall be effectively grounded.

Exception 1: This rule does not apply when such parts are guarded from accidental contact by unauthorized persons.

Exception 2: This rule does not apply where such parts are 8 feet or more above the ground.

Exception 3: This rule does not apply to metal conduit and cable sheaths inclosing communication conductors, or supply conductors of not more than 300 volts to ground, provided such conduit and sheaths are not exposed to probable contact with circuits of more than 300 volts to ground.

Recommendation: It is recommended that supply cables have the sheath bonded to any conduit extending above the ground surface.

Note: Metal conduit above ground which contains extensions from metal-sheathed underground cable is considered to be sufficiently grounded by the cable sheath, provided such sheath is in good contact with the earth or is connected to a good ground. (For method of grounding see section 9.)

C. Use of Ground as Part of Circuit.

In urban districts supply circuits shall not be designed to use the ground normally as the sole conductor for any part of the circuit.

Recommendation: It is recommended that such use be avoided in rural districts.

216. Arrangement of Switches.

A. Accessibility.

All switches shall be readily accessible to authorized persons.

216. Arrangement of Switches—Continued.

B. Indicating Open or Closed Position.

All switches shall indicate clearly whether they are open or closed.

C. Locking.

Pole-top switches accessible to unauthorized persons shall have provision for locking in both open and closed positions.

D. Uniform Position.

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

SEC. 22. RELATIONS BETWEEN VARIOUS CLASSES OF LINES

220. Relative Levels.

A. Standardization of Levels.

The levels at which different classes of conductors are to be located should be standardized where practicable for any given community by agreement of the utilities concerned.

Note: This practice facilitates the extension of lines and promotes the safety of the public and workers by permitting the relative levels and required clearances to be readily obtained on jointly or commonly used poles as well as at crossings and conflicts.

B. Relative Levels—Supply and Communication Conductors.

1. PREFERRED LEVELS.

Where supply and communication conductors cross each other or are in conflict, or are located on the same poles or towers, the supply conduc-

220. B. Relative Levels—Supply and Communication Conductors—Continued.

tors shall preferably be carried at the higher level.

Exception: This does not apply to trolley feeders which may be located for convenience approximately at the level of the trolley contact conductor.

Note: Supply lines generally use larger conductors than communication lines so there is less liability of contact between the two if the supply conductors are located in the upper position. This relative location also avoids the necessity of workmen on communication conductors passing through supply conductors and working above them and avoids the necessity of increasing the grade of construction required for communication conductors.

2. MINOR EXTENSIONS.

In localities where the practice of placing conductors of communication circuits for public use above supply conductors has been generally established, minor extensions may be made in either system, keeping the conductors in the same relative position. These extensions should not continue beyond a location at which it becomes practicable to change to the arrangement standardized by these rules.

3. SPECIAL CONSTRUCTION FOR SUPPLY CIRCUITS, THE VOLTAGE OF WHICH IS 550 VOLTS OR LESS AND CARRYING POWER NOT IN EXCESS OF 3,200 WATTS.

Where all circuits are owned or operated by one party or where cooperative consideration determines that the circumstances warrant and the necessary coordinating methods are employed, single-phase alternating-current or two-wire direct-current circuits carrying a voltage of 550 volts or less between conductors, with transmitted power not in excess of 3,200 watts, when involved in the joint use of poles with com-

220. B. Relative Levels—Supply and Communication Conductors—Continued.

munication circuits, may be installed in accordance with footnote 8 (3) of table 1 in rule 232, A and footnote (1) of table 11 in rule 238, A, 1, under the following conditions:

(a) That such supply circuits are of wire having a good grade of commercial double-braid weatherproof covering not smaller than No. 8 AWG medium hard-drawn copper or its equivalent in strength, and the construction otherwise conforms with the requirements for supply circuits of the same class.

(b) That the supply circuits be placed on the end and adjacent pins of the lowest through signal crossarm and that a 30-inch climbing space be maintained from the ground up to a point at least 24 inches above the supply circuits. The supply circuits shall be rendered conspicuous by the use of insulators of different form or color from others on the pole line or by stenciling the voltage on each side of the crossarm between the pins carrying each supply circuit, or by indicating the voltage by means of metal characters.

(c) That there shall be a vertical clearance of at least 2 feet between the crossarm carrying these supply circuits and the next crossarm above. The other pins on the crossarm carrying the supply circuits may be occupied by communication circuits used in the operation or control of a signal system or other supply system if owned, operated and maintained by the same company operating the supply circuits.

(d) That such supply circuits shall be equipped with arresters and fuses installed in the supply end of the circuit and where the

220. B. Relative Levels—Supply and Communication Conductors—Continued.

signal circuit is alternating current, the protection shall be installed on the secondary side of the supply transformer. The arresters shall be designed so as to break down at approximately twice the voltage between the wires of the circuit, but the break-down voltage of the arrester need not be less than 1,000 volts. The fuses shall have a rating not in excess of approximately twice the maximum operating current of the circuit, but their rating need not be less than 10 amperes. The fuses likewise shall in all cases have a rating of at least 600 volts, and where the supply transformer is a step-down transformer, shall be capable of opening the circuit successfully in the event the transformer primary voltage is impressed upon them.

(e) Such supply circuits when enclosed in effectively grounded metal-sheathed cable, or other cables carried on effectively grounded messenger, may be carried on a pole below communication attachments, with not less than 2 ft vertical separation between the supply cable and the lowest communication crossarm. Communication circuits other than those used in connection with the operation of the supply circuits shall not be carried in the same cable with such supply circuits.

(f) Where such supply conductors are carried below communication conductors, transformers and other apparatus associated therewith shall be attached only to the sides of the crossarm in the space between and at no higher level than, such supply wires.

(g) Lateral runs of such supply circuits carried in a position below the communication space

220. B. Relative Levels—Supply and Communication Conductors—Continued.

shall be protected through the climbing space by wood molding or equivalent covering, or shall be carried in multiple-conductor cable having a suitable substantial insulating covering, and such lateral runs shall be placed on the under side of the crossarm.

C. Relative Levels—Supply Lines of Different Voltage Classifications (as classified in table 11).

1. AT CROSSINGS OR CONFLICTS.

Where supply conductors of different voltage classifications cross each other or are in conflict, the higher-voltage lines shall preferably be carried at the higher level.

2. ON POLES USED ONLY BY SUPPLY CONDUCTORS.

Where supply conductors of different voltage classifications are on the same poles, relative levels should be as follows:

(a) Where all circuits are owned by one utility, the conductors of higher voltages should generally be placed above those of lower voltage.

Note: These relative levels will often avoid the necessity of increasing the grade of construction for crossarms, pins, and conductor fastenings of the lower-voltage conductors.

(b) Where different circuits are owned by separate utilities, the circuits of each utility may be grouped together and one group of circuits may be placed above the other group provided that the circuits in each group are located so that those of higher voltage are at the higher levels and that either of the following conditions is met:

(1) A vertical spacing of not less than 4 feet (or 6 feet where required by table 11,

220. C. Relative Levels—Supply Lines of Different Voltage Classifications—Continued.

rule 238, A, 1) is maintained between the nearest line conductors of the respective utilities (this space to be identified if necessary as a division space).

(2) Conductors of a lower voltage classification are at a higher level than those of a higher classification only where on the opposite side of the pole.

221. Avoidance of Conflict.

Two parallel pole lines, either of which carries supply conductors, shall where practicable be so separated from each other that neither conflicts with the other. If this is impracticable, then the conflicting line or lines shall be built of the grade of construction required by section 24 for a conflicting line or the two lines shall be combined in a single pole line.

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

A. Advantages.

Joint use of poles under suitable conditions and with certain types of circuits offers many advantages and promotes safety.

B. Cooperative Study.

Joint use involves contractual relations between utilities, consideration of service requirements, and economies as well as safety. It, therefore, requires cooperative study by the utilities concerned.

C. Conditions Under Which Joint Use is Desirable.

In the case of local or distribution circuits along the same highway or similar right-of-way, where, under the provisions of section 24 applying to joint use, grade C construction or less would be required, joint use is generally preferable to separate pole lines

222. C. Conditions Under Which Joint Use is Desirable—Continued.

(except sometimes in rural districts) unless the number of conductors is very large or the character of the circuits makes joint use undesirable.

Where circuits other than those mentioned above are involved, the choice between joint use of poles and separate pole lines shall be determined through cooperative consideration, by the utilities concerned, of all the factors involved, including the character of circuits, the total number and weight of conductors, tree conditions, number and location of branches and service drops, availability of right of way, etc. Where such joint use is mutually agreed upon, it shall be subject to the appropriate grade of construction as specified in section 24. Where such joint use is not employed, separate lines as specified in rule 223 shall be used.

In any event, joint use is preferable to separate lines where it would be impracticable to avoid an overbuilt conflict with separate lines.

223. Separate Pole Lines.

Where two separate pole lines are to be used, one of which carries supply conductors and the other communication conductors, they shall be separated, if practicable, so that neither conflicts with the other, but if within conflicting distance, they shall be separated as far as practicable and shall be built of the grade of construction required by section 24.

SEC. 23. CLEARANCES

230. General.

A. Application.

This section covers all clearances, including separations and climbing spaces, involving poles and wires. Clearances of lamps from pole surfaces, from spaces accessible to the general public, and height above ground are covered in rule 286, E.

230. General—Continued.

B. Constant-Current Circuits.

The clearances for constant-current circuits shall be determined on the basis of their nominal full-load voltage.

C. Metal-Sheathed Supply Cables.

As far as clearances are concerned, effectively grounded continuous metal-sheathed supply cables of all voltages and any supply cables supported on effectively grounded messengers, are classified the same as open supply wires of 0 to 750 volts between conductors.

D. Neutral Conductors.

Neutral conductors of supply circuits shall have the same clearances as the phase wires of the circuit with which they are associated, except that neutral conductors which are effectively grounded throughout their length and associated with circuits of 750 to 15,000 volts between conductors may have the same clearances as circuits of 0 to 750 volts between conductors.

E. Maintenance of Clearances.

The clearances required by this section shall be maintained at the specified values.

231. Horizontal Clearances of Supporting Structures from Other Objects.

Poles, towers, and other supporting structures and their guys and braces shall have the following horizontal clearances from other objects. The clearance shall be measured between the nearest parts of the objects concerned.

A. From Fire Hydrants.

Not less than 3 feet.

Recommendation: Where conditions permit, a clearance of not less than 4 feet is recommended.

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231. Horizontal Clearances of Supporting Structures from Other Objects—Continued.

B. From Street Corners.

Where hydrants are located at street corners, poles and towers should not be set so far from the corners as to make necessary the use of flying taps inaccessible from the poles.

C. From Curbs.

Not less than 6 inches measured to the street side of the curb.

D. From Railroad Tracks.

Where railroad tracks are paralleled or crossed by overhead lines, the poles shall, if practicable, be located not less than 12 feet from the nearest track rail.

Exception 1: At sidings a clearance of not less than 7 feet may be allowed, provided sufficient space for a driveway be left where cars are loaded or unloaded.

Exception 2: Supports for overhead trolley contact conductors may be located as near their own track rail as conditions require. If very close, however, permanent screens on cars will be necessary to protect passengers.

Exception 3: Where necessary to provide safe operating conditions which require an uninterrupted view of signals, signs, etc., along tracks, the parties concerned shall cooperate in locating poles to provide the necessary clearance where practicable.

232. Vertical Clearance of Wires Above Ground or Rails.

The vertical clearance of all wires above ground in generally accessible places or above rails shall be not less than the following:

232. Vertical Clearance of Wires Above Ground or Rails—Continued.

A. Basic Clearances.

The clearances in table 1 apply under the following conditions:

1. Temperature of 60° F, no wind, with final unloaded sag in the wire, or with initial unloaded sag in cases where wires are maintained approximately at initial unloaded sags.
2. Span lengths not greater than the following:

Loading district	Span lengths
	Feet
Heavy	[a]175
Medium	[a]250
Light	350

[a] 150 feet in heavy-loading district and 225 feet in medium-loading district for 3-strand conductors, each wire of which is 0.09 inch or less in diameter.

3. Voltages 0 to 50,000 volts between conductors.
4. Fixed supports for the conductor or wire.

(For other conditions, see rule 232, B.)

232. A. Basic Clearances—Continued.

TABLE 1.—*Minimum vertical clearance of wires above ground or rails*

[All voltages are between wires unless otherwise stated. Supply wires include trolley feeders]

Nature of ground or rails underneath wires	Guys; messengers; communication, span, and lightning protection wires; effectively grounded continuous-metal-sheath cables of all voltages	Open supply line wires, arc wires and service drops			Trolley contact conductors and associated span or messenger wires [1]	
		0 to 750 volts	750 to 15,000 volts[14]	15,000 to 50,000 volts	0 to 750 volts to ground	Exceeding 750 volts to ground
WHERE WIRES CROSS OVER						
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
Track rails of railroads (except electrified railroads using overhead trolley conductors) handling freights cars on top of which men are permitted[2, 16]	[3, 15] 27	[3] 27	[3] 28	30	[4] 22	[4] 22
Track rails of railroads (except electrified railroads using overhead trolley conductors) not included above [2]	18	18	20	22	[5] 18	[5] 20
Public streets, alleys or roads in urban or rural districts	[6, 13] 18	18	20	22	[5] 18	[5] 20
Driveways to residence garages	10	10	20	22	[5] 18	[5] 20
Spaces or ways accessible to pedestrians only	[7] 15	[8] 15	15	17	[9] 16	[9] 18
WHERE WIRES RUN ALONG, AND WITHIN THE LIMITS OF PUBLIC HIGHWAYS OR OTHER PUBLIC RIGHTS-OF-WAY FOR TRAFFIC						
Streets or alleys in urban districts	[10, 11, 13] 18	[10] 18	20	22	[5] 18	[5] 20
Roads in rural districts	[10, 11, 12] 14	[10] 15	18	20	[5] 18	[5] 20

Footnotes on following page.

232. A. Basic Clearances—Continued.

[1] Where subways, tunnels, or bridges require it, less clearances above ground or rails than required by table 1 may be used locally. The trolley contact conductor should be graded very gradually from the regular construction down to the reduced elevation.

[2] For wire crossings over railways handling only cars considerably lower than ordinary freight cars, the clearance may be reduced by an amount equal to the difference in height between the highest car handled and the highest ordinary freight car, but the clearance shall not be reduced below that required for street crossings.

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

[4] In communities where 21 feet has been established, this clearance may be continued if carefully maintained. The elevation of the contact conductor should be the same in the crossing and next adjacent spans. (See rule 289, D, 2, for conditions which must be met where uniform height above rail is impracticable.)

[5] In communities where 16 feet has been established for trolley contact conductors 0 to 750 volts to ground, or 18 feet for trolley contact conductors exceeding 750 volts, or where local conditions make it impracticable to obtain the clearance given in the table, these reduced clearances may be used if carefully maintained.

[6] If a communication service drop, or a guy which is effectively insulated against the highest voltage to which it is exposed, up to 8,700 volts, crosses a street, alley or road, the clearance may be reduced to 16 feet at the side of the traveled way.

[7] This clearance may be reduced to the following values:

	Feet
(1) For communication conductors of circuits limited to 160 volts to ground, and communication cables	8
(2) For conductors of other communication circuits	10
(3) For guys	8

[8] This clearance may be reduced to the following values:

	Feet
(1) Supply wires (except trolley contact wires) limited to 300 volts to ground	12
(2) Supply wires (except trolley contact wires) limited to 150 volts to ground and located at entrances to buildings	10
(3) Where supply circuits of 550 volts or less, with transmitted power of 3,200 watts or less, are run along fenced (or otherwise guarded) private rights-of-way in accordance with the provisions specified in rule 220, B, 3	10

[9] Trolley contact conductors for industrial railways when not along or crossing over roadways may be placed at a less height if suitably guarded.

[10] Where a pole line along a road is located relative to fences, ditches, embankments, etc., so that the ground under the line will never be traveled except by pedestrians, this clearance may be reduced to the following values:

	Feet
(1) Communication conductors limited to 160 volts to ground, and communication cables	8
(2) Conductors of other communication circuits	10
(3) Supply conductors	12

[11] No clearance from ground is required for anchor guys not crossing streets, driveways, roads, or pathways, nor for anchor guys provided with traffic guards and paralleling sidewalk curbs.

[12] This clearance may be reduced to 13 feet for communication conductors where no part of the line overhangs any part of the highway which is ordinarily traveled, and where it is unlikely that loaded vehicles will be crossing under the line into a field.

[13] Where communication wires or cables cross over or run along alleys, this clearance may be reduced to 15 feet.

[14] A conductor which is effectively grounded throughout its length and is associated with a circuit of 750 to 15,000 volts between conductors may have the clearances specified for open supply wires of 0 to 750 volts.

[15] This value may be reduced to 25 feet for guys and for cables carried on messengers.

[16] Adjacent to overhead bridges which restrict the practice of permitting men on top of cars, these clearances may be reduced, within the restricted area, by mutual agreement between the parties at interest, but in no case shall the wires or cables be at levels below the undersurface of the bridge.

232. Vertical Clearance of Wires Above Ground or Rails—Continued.

B. Increased Clearances.

Greater clearances than specified in table 1 (rule 232, A) shall be provided where required by 1, 2, and 3 below. Increases are cumulative where more than one apply.

Exception: Increased clearances are not required for trolley contact conductors, for guys, or for cable supported by messenger.

1. SPANS LONGER THAN SPECIFIED IN RULE 232, A, 2. In applying the following rules, the "point of crossing" in the case of roads, streets, alleys and driveways is considered to be the edge of the traveled way farthest from the nearer support of the crossing span. In the case of a railroad crossing, it is the track rail which is farthest from the nearer support of the crossing span. In other situations it is the location under the conductors of any topographical feature which is the determinant of the clearance.

(a) WHERE POINT OF CROSSING OCCURS AT POINT OF MAXIMUM TOTAL SAG OF THE CONDUCTOR.

(1) GENERAL. For spans exceeding the limits specified in rule 232, A, 2, above, the clearance specified in table 1 shall be increased by 0.1 foot for each 10 feet of the excess of span length over such limits. See (3) below.

(2) RAILROAD CROSSINGS. For spans exceeding the limits specified in rule 232, A, 2, above, the clearance specified in table 1 shall be increased by the following amounts for each 10 feet by which the

232. B. Increased Clearances—Continued.

crossing span length exceeds such limits. See (3) below.

Loading district	Amount of increase per 10 feet	
	Large conductors	Small[1] conductors
	Feet	*Feet*
Heavy and medium	0. 15	0. 30
Light	. 10	. 15

[1] A small conductor is a conductor having an over-all diameter of metallic material equal to or less than the following values:

Material	Outside diameter of conductor	
	Solid	Stranded
	Inches	*Inches*
All copper	0. 160	0. 250
Other than all copper	. 250	. 275

(3) LIMITS. The maximum additional clearance need not exceed the following percentages of the "maximum sag increase" for the conductor concerned:

Loading district	Percentage
Heavy	75
Medium	85
Light	75

The "maximum sag increase" to which these percentages apply is the arithmetic difference between final unloaded sag at 60° F, no wind, and the maximum total sag under the entire conductor loading of rule 251 for the loading district con-

232. B. Increased Clearances—Continued.

cernėd, or under 120° F, no wind, whichever sag is the greater, computed for the span length for which such difference is greatest.

(b) WHERE POINT OF CROSSING IS NOT AT POINT OF MAXIMUM TOTAL SAG OF THE CONDUCTOR.

Under these conditions the required clearance may be obtained by multiplying the clearance determined by rules 232, A and 232, B, 1 (a) by the following factors, but in no case shall the clearance be less than required by table 1:

Distance from nearer support of crossing span to point of crossing in percentage of crossing span length	Factors
5	0. 85
10	. 88
15	. 91
20	. 94
25	. 96
30	. 98
35	. 99
40 to 50	1. 00
Interpolate for intermediate values	

2. VOLTAGES EXCEEDING 50,000 VOLTS BETWEEN CONDUCTORS.

For these voltages the clearances given in table 1 (rule 232, A) shall be increased at the rate of 0.5 inch for each 1,000 volts of the excess.

3. CONDUCTORS SUPPORTED BY SUSPENSION-TYPE INSULATORS AT CROSSINGS OVER TRACK RAILS.

The clearance shall be increased by such an amount that the values specified in table 1

232. B. Increased Clearances—Continued.

(rule 232, A) will be maintained in case of a broken conductor in either adjoining span, if the conductor is supported as follows:

(a) At one support by suspension-type insulators in a suspended position, and at the other support by insulators which are not free to swing (including semistrain-type insulators).

(b) At one support by strain insulators, and at the other support by semistrain-type insulators.

4. METHODS OF AVOIDING THIS INCREASE OF CLEARANCE.

Any of the following construction methods will avoid the necessity for the increase in clearance required by rule 232, B, 3:

(a) *Suspension-type insulators* in a suspended position at both supports.

(b) *Semistrain-type insulators* at both supports.

(c) *Arrangement of insulators* so that they are restrained from displacement toward the crossing.

C. Supply Pole Wiring at Underground Risers.

Supply wires connecting to underground systems shall not be run open closer to the ground than is indicated by table 2:

TABLE 2.—*Clearance above ground for open supply wiring*

Location on pole	Voltage between conductors		
	0 to 750 volts	750 to 15,000 volts	More than 15,000 volts
	Feet	*Feet*	*Feet*
Side of pole adjacent to vehicular traffic	14	16	18
Side of pole not adjacent to vehicular traffic	8	11	13

233. Wire-Crossing Clearances.

The clearance between any two wires crossing each other and carried on different supports shall be not less than the following:

A. **Basic Clearances.**

The clearances given in table 3 below apply under the following conditions:

1. Temperature of 60° F, no wind, with the upper conductor or wire at its final unloaded sag and the lower conductor or wire at its initial unloaded sag.
2. Span lengths not greater than the following for the upper conductor or wire:

Loading district	Span lengths
	Feet
Heavy	[1] 175
Medium	[1] 250
Light	350

[1] 150 feet in heavy loading district and 225 feet in medium loading district for 3-strand conductors, each wire of which is 0.09 inch or less in diameter.

3. Voltages 0 to 50,000 volts between conductors.
4. Fixed supports for the upper conductor or wire.

233. A. Basic Clearances—Continued.

TABLE 3.—*Wire-crossing clearances*

[All voltages are between wires except for trolley contact conductors where voltages are to ground]

[The insertion of a given clearance in italics indicates that in general the lines operating at the voltage named above this clearance should not cross over the lines at the voltage to the left of the clearance in italics]

Nature of wires crossed over	Communication wires, including cables and messengers	Open supply wires 0 to 750 volts; supply cables, all voltages, having effectively grounded continuous metal sheaths or messengers; messengers associated with such cables		Open supply wires and service drops [6]		Guys, span wires, lightning-protection wires
		Line wires	Service drops	750 to 8,700 volts	8,700 to 50,000 volts	
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
Communication, including cables and messengers	[2] 2	[9 3] 4	[9] 2	[7] 4	[10] 6	[2] 2
Supply cables, all voltages, having effectively grounded continuous metal sheaths or messengers; messengers associated with such cables	*4*	2	2	2	4	2
Open supply wires:						
0 to 750 volts	*4*	2	2	2	4	2
750 to 8,700 volts	*4*	*2*	*4*	2	4	4
8,700 to 50,000 volts	*6*	*4*	*6*	*4*	4	4
Trolley contact conductors	[4] 4	[4 5] 4	[4] 4	6	6	[4] 4
Guys, span wires, lightning-protection wires, service drops 0 to 750 volts	[2 8] 2	2	2	4	4	[1 2] 2

Footnotes on following page.

233. Wire-Crossing Clearances—Continued.

B. Increased Clearances.

Greater clearances than given in table 3 (rule 233, A) shall be provided under the following conditions. The increases in 1, 2, and 3 below are cumulative where more than one are applicable.

1. CROSSING SPANS LONGER THAN SPECIFIED IN RULE 233, A, 2.

Under these conditions the clearances specified in table 3 shall be increased as follows:

(a) Where the crossing occurs at the point of maximum total sag in the upper conductor, the clearances of table 3 shall be increased by the following amounts for each 10 feet by which the crossing span

---

[1] Completely insulated sections of guys attached to supporting structures having no conductor of more than 8,700 volts may have less than this clearance from each other.

[2] The clearance of communication conductors and their guy, span, and messenger wires from each other in locations where no other classes of conductors are involved may be reduced by mutual consent of the parties concerned, subject to the approval of the regulatory body having jurisdiction, except for fire-alarm wires and wires used in the operation of railroads, or where one set of conductors is for public use and the other used in the operation of supply systems.

[3] Except where neutral conductors of primary supply circuits are concerned, a clearance of 2 feet may be permitted where the supply conductor is above the communication conductor, provided the crossing is not within 6 feet of any pole concerned in the crossing and the voltage to ground does not exceed 300 volts. (See note 9.)

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

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

[6] A conductor which is effectively grounded throughout its length and is associated with a circuit of 750 to 15,000 volts between conductors may have the clearances specified for open supply wires of 0 to 750 volts.

[7] This clearance shall be increased to 6 feet where the supply wires cross over a communication line within 6 feet horizontally of a communication pole.

[8] This clearance shall be increased to 4 feet where communication cables cross over open supply service wires.

[9] Where a 2-foot clearance is required at 60° F, and where conditions are such that the sag in the upper conductor would increase more than 1.5 feet at the crossing point under the applicable loading of rule 251, the 2-foot clearance shall be increased by the amount of sag increase less 1.5 feet.

[10] Multigrounded wye circuits not exceeding 8,700 volts to ground may have a 4-foot clearance if the lowest supply wire at the crossing under conditions of 60° F, no wind, and final unloaded sag is not lower than a straight line joining the points of support of the highest communication conductor, provided it is not within 6 feet horizontally of a communication pole.

233. B. Increased Clearances—Continued.

length exceeds the limits specified in rule 233, A, 2:

Loading district	Amount of increase per 10 feet	
	Large conductors	Small conductors [1]
	Feet	*Feet*
Heavy and medium	0. 15	0. 30
Light	. 10	. 15

[1] A small conductor is a conductor having an over-all diameter of metallic material equal to or less than the following values:

Material	Outside diameter of conductor	
	Solid	Stranded
	Inches	*Inches*
All copper	0. 160	0. 250
Other than all copper	. 250	. 275

The maximum additional clearance need not exceed the following percentages of the "maximum sag increase" for the conductor concerned:

Loading district	Percentage
Heavy	75
Medium	85
Light	75

The "maximum sag increase" to which these percentages apply is the arithmetic difference between final unloaded sag at 60° F, no wind, and the maximum total sag under the entire conductor loading of

233. B. Increased Clearances—Continued.

rule 251 for the loading district concerned, or under 120° F, no wind, whichever sag is the greater, computed for the span length for which such difference is greatest.

(b) If the crossing point is located elsewhere than at the point of maximum total sag in the upper span, the required clearance may be obtained by multiplying the clearance determined in rule 233, A and B, 1 (a) by the following factors, but in no case shall the clearance be less than required by table 3:

Distance from nearer support of crossing span to point of crossing, in percentage of crossing span length	Factors for basic clearance of—	
	4 feet	6 feet
5	0. 35	0. 47
10	. 47	. 58
15	. 60	. 68
20	. 71	. 78
25	. 82	. 85
30	. 90	. 92
35	. 96	. 98
40 to 50	1. 00	1. 00
Interpolate for intermediate values.		

2. VOLTAGES EXCEEDING 50,000 VOLTS BETWEEN CONDUCTORS.

For these voltages the clearances given in table 3 (rule 233, A) shall be increased at the rate of 0.5 inch for each 1,000 volts of the excess.

3. CONDUCTORS SUPPORTED BY SUSPENSION-TYPE INSULATORS AT CROSSINGS OVER COMMUNICATION WIRES.

For such conductors the clearance shall be increased by such an amount that the values

233. B. Increased Clearances—Continued.

specified in table 3 (rule 233, A) will be maintained in case of a broken conductor in either adjacent span, provided such conductor is supported as follows:

(a) At one support by suspension-type insulators in a suspended position, and at the other support by insulators not free to swing (including semistrain-type insulators).

(b) At one support by a strain insulator, and at the other support by a semistrain-type insulator.

4. METHODS OF AVOIDING THIS INCREASE OF CLEARANCE.

Any of the following construction methods will avoid the necessity for the increase in clearance required by rule 233, B, 3:

(a) *Suspension-type insulators* in a suspended position at both supports.

(b) *Semistrain-type insulators* at both supports.

(c) *Arrangement of insulators* so that they are restrained from displacement toward the crossing.

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

A. Clearances from Conductors of Another Line.

The clearance in any direction between any conductor of one line and any conductor of a second and conflicting line shall be not less than the largest value required by 1, 2, or 3 below at 60° F, no wind:

1. Four feet.
2. The values required by rule 235, A, 2, (a) (1), or (2) for separation between conductors on the same support.
3. The apparent sag of the conductor having the greater sag, plus 0.2 inch per kilovolt of the highest voltage concerned.

234. A. Clearances from Conductors of Another Line—Continued.

Exception: In situations where supply-line conductors only are involved, the clearance required by 3 above need not be greater than the value required by rule 233, A and B, for a center-span crossing, assuming the conductor having the larger sag swinging through an arc of 45° from the vertical.

B. Clearances from Supporting Structures of Another Line.

Conductors of any line passing near a pole or similar supporting structure of a second line, without being attached thereto, shall have clearances from any part of such structure not less than the larger value required by either 1 or 2 below at 60° F, no wind:

1. Three feet if practicable.
2. The values required by rule 235, A, 2, (a) (1) and (2) for separation between similar conductors on the same support, increased by 1 inch for each 2 feet of the distance from the supporting structure of the second line to the nearest supporting structure of the first line.

   The climbing space on the structure of the second line shall in no case be reduced by a conductor of the first line.

C. Clearances from Buildings.

1. GENERAL.

   Conductors shall be arranged and maintained so as to hamper and endanger firemen as little as possible in the performance of their duties.

2. LADDER SPACE.

   Where buildings exceed three stories (or 50 feet) in height, overhead lines should be arranged where practicable so that a clear space or zone at least 6 feet wide will be left, either adjacent to the building or beginning not over 8 feet from

234. C. Clearances from Buildings—Continued.

the building, to facilitate the raising of ladders where necessary for fire fighting.

Exception: This requirement does not apply where it is the unvarying rule of the local fire departments to exclude the use of ladders in alleys or other restricted places which are generally occupied by supply lines.

3. OPEN SUPPLY CONDUCTORS ATTACHED TO BUILDINGS.

Where the permanent attachment of open supply conductors of any class to buildings is necessary for an entrance, such conductors shall meet the following requirements:

(a) Conductors of more than 300 volts to ground shall not be carried along or near the surface of the building unless they are guarded or made inaccessible.

(b) Clearance of wires from building surface shall be not less than those required in table 9 (rule 235, A, 3, (a)) for clearance of conductors from pole surfaces.

4. CONDUCTORS PASSING BY OR OVER BUILDINGS.

(a) MINIMUM CLEARANCES. Unguarded or accessible supply conductors carrying voltages in excess of 300 volts between conductors shall not come closer to any building or its attachments (balconies, platforms, etc.) than listed below, except that this rule should not be interpreted as restricting the installation of a trolley contact conductor over the approximate center line of the track it serves.

(1) SPANS 0 TO 150 FEET. For spans of 0 to 150 feet, the clearances shall be as given in table 4.

834055°—49——6

234. C. Clearances from Buildings—Continued.

TABLE 4.—*Clearances of supply conductors from buildings*

[All voltages are between conductors]

Voltage of supply conductors	Horizontal clearance	Vertical clearance
	Feet	*Feet*
300 to 8,700	3	8
8,700 to 15,000	8	8
15,000 to 50,000	10	10
Exceeding 50,000	10 plus 0.5 inch per kv in excess.	10 plus 0.5 inch per kv in excess.

(2) SPANS EXCEEDING 150 FEET. Where span lengths exceed 150 feet, the increased clearances required by rule 232, B, 1 shall be provided.

Exception: These increased clearances are not required where the voltage of the supply conductors is from 300 to 8,700 volts between conductors.

(b) GUARDING OF SUPPLY CONDUCTORS. Supply conductors of 300 volts or more between conductors shall be properly guarded by grounded conduit, barriers, or otherwise, under the following conditions:

(1) Where the clearances set forth in table 4 (rule 234, C, 4, (a), (1)) cannot be obtained.

(2) Where such supply conductors are placed near enough to windows, verandas, fire escapes, or other ordinarily accessible places, to be exposed to contact by persons.

Note: Supply conductors in grounded metal-sheathed cable are considered to be guarded within the meaning of this rule.

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

D. Clearances from Bridges.

1. CLEARANCES OF CONDUCTORS FROM BRIDGES.

Supply conductors, not installed in grounded conduit or metal-sheath cable, which pass under, over, or near a bridge shall have clearances therefrom not less than given in table 5.

2. GUARDING TROLLEY-CONTACT CONDUCTORS LOCATED UNDER BRIDGES.

(a) WHERE GUARDING IS REQUIRED. Guarding is required where the trolley-contact conductor is located so that a trolley pole leaving the conductor can make simultaneous contact between it and the bridge structure.

TABLE 5.—*Clearances from bridges*

Voltages between conductors	Readily accessible portions (other than traveled ways [1]) of any bridge, including wing walls or bridge attachments		From ordinarily inaccessible portions [2] of bridges (other than brick, concrete, or masonry) and from abutments	
	For conductors attached to bridge [3]	For conductors not attached to bridge	For conductors attached to bridge [3 5]	For conductors not attached to bridge [4 5]
	Feet	*Feet*	*Feet*	*Feet*
0 to 2,500	3. 0	3. 0	0. 5	3. 0
Over 2,500 to 5,000	3. 0	3. 0	1. 0	3. 0
Over 5,000 to 8,700	3. 0	3. 0	3. 0	3. 0
Over 8,700 to 15,000	5. 0	5. 0	5. 0	5. 0
Over 15,000 to 25,000	7. 5	7. 5	7. 5	7. 5
Over 25,000 to 35,000	7. 5	9. 0	7. 5	9. 0
Over 35,000 to 50,000	7. 5	12. 0	7. 5	12. 0

[1] Where over traveled ways on or near bridges, the clearances of rule 232 apply.
[2] Bridge seats of steel bridges carried on masonry, brick, or concrete abutments which require frequent access for inspection shall be considered as readily accessible portions.
[3] Conductors should have clearance not less than given in this column, where practicable.
[4] Conductors should have the clearances given in this column increased as much as practicable.
[5] Where conductors passing under bridges are adequately guarded against contact by unauthorized persons and can be deenergized for maintenance of the bridge, clearances of the conductors from the bridge, at any point, may have the clearances specified in table 9 for clearance from surfaces of crossarms plus one-half the final unloaded sag of the conductor at that point.

234. D. Clearances from Bridges—Continued.

(b) Nature of Guarding. Guarding shall consist of a substantial inverted trough of nonconducting material located above the contact conductor, or of other suitable means of preventing contact between the trolley pole and the bridge structure.

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

A. Separation Between Conductors on Pole Lines.

1. application of rule.

(a) Multiconductor Wires or Cables. Cables, and duplex, triple or paired conductors supported on insulators or messengers, whether single or grouped, are for the purposes of this rule considered single conductors even though they may contain individual conductors not of the same phase or polarity.

(b) Conductors Supported by Messengers or Span Wires. Clearances between individual wires or cables supported by the same messenger, or between any group and its supporting messenger, or between a trolley feeder, supply conductor, or communication conductor, and their respective supporting span wires, are not subject to the provisions of this rule.

(c) Measurement of Clearances. The clearances and separations stated may be measured from the center of the supporting insulator instead of from the conductor itself.

2. horizontal separations between line conductors.

(a) Fixed Supports. Line conductors attached to fixed supports shall have horizontal separations from each other not less than the

235. A. Separation Between Conductors on Pole Lines—Continued.

larger value required by either (1) or (2) below for the situation concerned.

Exception 1: The pin spacing at buckarm construction may be reduced as specified in rule 236, F, to provide climbing space.

Exception 2: The pin spacing at bridge fixtures may be reduced as specified in rule 235, C.

Exception 3: Grades D and N need meet only the requirements of (1) below.

Exception 4: These clearances do not apply where conductors have insulating covering adequate for the voltage concerned.

(1) MINIMUM HORIZONTAL SEPARATION BETWEEN LINE CONDUCTORS OF THE SAME OR DIFFERENT CIRCUITS. Separations shall be not less than given in table 6.

TABLE 6.—*Minimum horizontal separation at supports between line conductors of the same or different circuits*

[All voltages are between conductors except for railway feeders, which are to ground]

Class of circuit	Separation	Notes
	Inches	
Communication conductors	6	Preferable minimum. Does not apply at conductor transposition points.
	3	Permitted where pin spacings less than 6 inches have been in regular use. Does not apply at conductor transposition points.
Railway feeders:		
0 to 750 volts, No. 4/0 or larger	6	
0 to 750 volts, smaller than No. 4/0	12	Where 10- to 12-inch separation has already been established by practice, it may be continued, subject to the provisions of rule 235, A, 2, (*a*), (2), for conductors having apparent sags not over 3 feet and for voltages not exceeding 8,700.
750 volts to 8,700 volts	12	
Other supply conductors:		
0 to 8,700 volts	12	
For all conductors of more than 8,700 volts add for each 1,000 volts in excess of 8,700 volts	0.4	

235. A. Separation Between Conductors on Pole Lines—Continued.

(2) SEPARATIONS ACCORDING TO SAGS. The separation at the supports of conductors of the same or different circuits of grades B, or C shall in no case be less than the values given by the following formulas, at 60° F, no wind. The requirements of rule 235, A, 2, (a), (1) apply if they give a greater separation than this rule.

For line conductors smaller than No. 2 AWG:

Separation$=$0.3 inch per kilovolt$+7\sqrt{(S/3)-8}$.

For line conductors of No. 2 AWG or larger:

Separation$=$0.3 inch per kilovolt$+8\sqrt{S/12}$.

S is the apparent sag in inches of the conductor having the greater sag, and the separation is in inches.

TABLE 7.—*Separation in inches required for line conductors smaller than No. 2 AWG*

Voltages between conductors	Sag (in inches)						
	36	48	72	96	120	180	240
2,400	14.5	20.5	28.5	35.0	40.5	51.5	60.0
7,200	16.0	22.0	30.0	36.5	42.0	52.5	61.5
13,200	18.0	24.0	32.0	38.5	43.5	54.5	63.5
23,000	21.0	27.0	35.0	41.5	46.5	57.5	66.5
34,500	24.5	30.5	38.5	44.5	50.5	61.0	70.0
46,000	28.0	34.0	42.0	48.0	53.5	64.5	73.0
69,000	--------	40.5	48.5	55.0	60.5	71.0	80.0

235. A. Separation Between Conductors on Pole Lines—Continued.

TABLE 8.—*Separation in inches required for line conductors No. 2 AWG or larger*

Voltages between conductors	Sag (in inches)						
	36	48	72	96	120	180	240
2,400	14.5	16.5	20.5	23.5	26.0	31.5	36.5
7,200	16.0	18.0	22.0	25.0	27.5	33.0	38.0
13,200	18.0	20.0	23.5	26.5	29.5	35.0	39.5
23,000	21.0	23.0	26.5	29.5	32.0	38.0	42.5
34,500	24.0	26.5	30.0	33.0	35.5	41.5	46.0
46,000	27.5	30.0	33.5	36.5	39.0	45.0	49.5
69,000	--------	36.5	40.5	43.5	46.0	51.5	56.5

(b) SUSPENSION INSULATORS NOT RESTRAINED FROM MOVEMENT. Where suspension insulators are used and are not restrained from movement, the conductor separation shall be increased so that one string of line insulators may swing transversely through an angle of 45° from a vertical position without reducing the values given in (a) above.

3. CLEARANCES IN ANY DIRECTION FROM LINE CONDUCTORS TO SUPPORTS, AND TO VERTICAL OR LATERAL CONDUCTORS, SPAN OR GUY WIRES, ATTACHED TO THE SAME SUPPORT.

(a) FIXED SUPPORTS. Clearances shall be not less than given in table 9.

235. A. Separation Between Conductors on Pole Lines—Continued.

TABLE 9.—*Minimum clearance in any direction from line conductors to supports, and to vertical or lateral conductors, span or guy wires attached to the same support*

[All voltages are between conductors]

Clearance of line conductors from—	Communication lines—		Supply lines		
			0 to 8,700 volts		Exceeding 8,700 volts, add for each 1,000 volts of excess
	In general	On jointly used poles	In general	On jointly used poles	
Vertical and lateral conductors:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Of same circuit	3	3	3	3	0.25
Of other circuits	3	3	[6] 6	[6] 6	.4
Span and guy wires attached to same pole:					
General	[8] 3	[1 8] 6	6	6	.4
When parallel to line	[8] 3	[1 8] 6	[1] 12	[1] 12	.4
Lightning-protection wires parallel to line	([2 5])	([2 5])	([2 5])	([2 5])	.4
Surfaces of crossarms	[3] 3	[3] 3	3	3	.25
Surfaces of poles	[3] 3	[3] 5	[7] 3	[4 7] 5	.25

[1] For guy wires, if practicable. For clearances between span wires and communication conductors, see rule 238, E, 3.

[2] Clearance shall not be less than the separation required by table 6 or rule 235, A, 2, (a), (2) between two line conductors of the voltage concerned.

[3] Communication conductors may be attached to supports on the sides or bottoms of crossarms or surfaces of poles with less clearances, if at least 40 inches from any supply line conductor of less than 8,700 volts and at least 60 inches from any supply line conductor of more than 8,700 volts carried on the same pole.

[4] This clearance applies only to supply conductors carried on crossarms below communication conductors, on joint poles. Where supply conductors are above communication conductors the clearance shall be at least 3 inches.

[5] For the purpose of applying the above table, the voltage of lightning-protection wires shall be considered as being the voltage to ground of the associated supply conductors.

[6] For supply circuits of 0 to 750 volts, this clearance may be reduced to 3 inches.

[7] A neutral conductor which is effectively grounded throughout its length and is associated with a circuit of 0 to 15,000 volts between conductors may be attached directly to the pole surface.

[8] Guys and messengers may be attached to the same strain plates or to the same throughbolts.

235. A. Separation Between Conductors on Pole Lines—Continued.

(b) Suspension Insulators not Restrained From Movement. Where suspension insulators are used and are not restrained from movement, the conductor clearances from surfaces of supports, from span or guy wires, or from vertical or lateral conductors shall be such that the values of clearances required by (a) above will be maintained with an insulator swing of 45° from the vertical position on steel or concrete supports, or 30° if on wood poles.

4. CONDUCTOR SEPARATION—VERTICAL RACKS.

Conductors or cables may be carried on vertical racks or separate brackets other than wood placed vertically at one side of the pole and securely attached thereto, if all the following conditions are met:

(a) The voltage between conductors shall be not more than 750 volts, except that cables having effectively grounded continuous metal sheath may carry any voltage.

(b) Conductors shall be of the same material or materials.

(c) Vertical spacing between conductors shall be not less than the following:

Span length	Vertical clearance between conductors
Feet	*Inches*
0 to 150	4
150 to 200	6
200 to 250	8
250 to 300	12

(See table 9, rule 235, A, 3, for necessary clearances from pole surfaces and rule 236, G, for method of providing climbing space.)

235. A. Separation Between Conductors on Pole Lines—Continued.

5. SEPARATION BETWEEN SUPPLY CIRCUITS OF DIFFERENT VOLTAGE CLASSIFICATIONS ON THE SAME CROSSARM.

Supply circuits of any one voltage classification as given in table 11 (rule 238, A, 1) may be maintained on the same crossarm with supply circuits of the next consecutive voltage classification only under the following conditions:

(*a*) If they occupy pin positions on opposite sides of the pole.

(*b*) If in bridge-arm or side-arm construction they are separated by a distance of not less than the climbing space required for the higher voltage concerned and provided for in rule 236.

(*c*) If the higher-voltage conductors occupy the outer pin positions and the lower-voltage conductors the inner pin positions.

(*d*) If series lighting or similar supply circuits are ordinarily dead during periods of work on or above the crossarm concerned.

(*e*) If the two circuits concerned are communication circuits used in the operation of supply lines, and supply circuits of less than 8,700 volts, and are owned by the same utility, provided they are installed as in (a) or (b) above.

B. Separation Between Conductors Attached to Buildings.

Separation of wires from each other shall be not less than those required in table 6 (rule 235, A, 2, (a) (1)) for separation of conductors from each other at supports.

Exception: Conductors on vertical racks or separate brackets other than wood placed vertically meeting the requirements of rule 235, A, 4 may have the separations specified in that rule.

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

C. Separation Between Conductors Attached to Bridges.

Supply conductors attached to bridges and supported at frequent intervals may have less separation at supports than required by rule 235, A, 2, (*a*), (1) and (2). The separation shall be not less than the clearance between supply conductors and the surfaces of poles or crossarms required by rule 235, A, 3, (a), or less than the following:

Span length:	Separation *Inches*
0 to 20 feet	6
20 to 50 feet	9

236. Climbing Space.

A. Location and Dimensions.

1. A climbing space having the horizontal dimensions specified in rule 236, E, shall be provided past any conductors, crossarms, or other parts.
2. The climbing space need be provided on one side or corner of the pole only.
3. The climbing space shall extend vertically past any conductor or other part between levels above and below the conductor as specified in rule 236, E, F, G, and I, but may otherwise be shifted from any side or corner of the pole to any other side or corner.

B. Portions of Supporting Structures in Climbing Space.

Portions of the pole or structure when included in one side or corner of the climbing space are not considered to obstruct the climbing space.

C. Crossarm Location Relative to Climbing Space.

Recommendation: Crossarms should be located on the same side of the pole.

Exception: This recommendation does not apply where double crossarms are used on any pole or where crossarms on any pole are not all parallel.

236. Climbing Space—Continued.

D. Location of Supply Apparatus Relative to Climbing Space.

Transformers, regulators, lightning arresters, and switches when located below conductors or other attachments shall be mounted outside of the climbing space.

E. Climbing Space Through Conductors on Crossarms.

1. CONDUCTORS OF SAME VOLTAGE CLASSIFICATION ON SAME CROSSARM.

Climbing space between conductors shall be of the horizontal dimensions specified in table 10 (rule 236, E, 3), and shall be provided both along and across the line, and shall be projected vertically not less than 40 inches above and below the limiting conductors. Where communication conductors are above supply conductors of more than 8,700 volts, the climbing space shall be projected vertically at least 60 inches above the highest supply conductor.

Exception 1: This rule does not apply if it is the unvarying practice of the employers concerned to prohibit employees from ascending beyond the conductors of the given line, unless the line is killed.

Exception 2: For supply conductors carried on a pole in a position below communication facilities in the manner permitted in rule 220, B, 3, the climbing space need not extend more than 2 feet above such supply space.

2. CONDUCTORS OF DIFFERENT VOLTAGE CLASSIFICATIONS ON SAME CROSSARM.

The climbing space shall be that required by table 10 (rule 236, E, 3) for the highest voltage of any conductor bounding the climbing space. The climbing space shall extend vertically to the limits specified in rule 236, E, 1, and the exceptions thereto.

236. E. Climbing Space Through Conductors on Cross-arms—Continued.

3. HORIZONTAL CLIMBING-SPACE DIMENSIONS.

TABLE 10.—*Minimum horizontal dimensions of climbing space*

Character of conductors adjacent to climbing space	Voltage of conductors		Horizontal dimensions of climbing space (inches)			
			On poles used solely by—		On jointly used poles	
	To ground	Between wires	Communication conductors	Supply conductors	Supply conductors above communication conductors	Communication conductors above supply conductors [1]
Communication conductors.	0 to 150	------------	No requirement.	------------	([2])	No requirement.
	Exceeding 150.	------------	24 recommended.	------------	([2])	24 recommended.
Supply conductors.	Less than 300.	------------	------------	24	24	30.
	300 to	8,700	------------	30	30	30.
	------------	8,700 to 15,000.	------------	36	36	36.
	------------	Exceeding 15,000.	------------	More than 36.[3]	More than 36.[3]	More than 36.[3]

[1] This relation of levels is not, in general, desirable and should be avoided where practicable.
[2] Climbing space shall be the same as required for the supply conductors immediately above, with a maximum of 30 inches, except that a climbing space of 16 inches across the line may be employed for communication cables or conductors where the only supply conductors at a higher level are secondaries (0 to 750 volts between conductors) supplying airport or airway marker lights or crossing over the communication line and attached to the pole top or to a pole-top extension fixture.
[3] Where practicable. (Attention is called to the operating requirements of rule 422, part 4 of this code.)

F. Climbing Space on Buckarm Construction.

The full width of climbing space shall be maintained on buckarm construction and shall extend vertically in the same position at least 40 inches (or 60 inches where required by rule 236, E, 1) above and below any limiting conductor.

Method of Providing Climbing Space on Buckarm Construction. With circuits of less than 8,700 volts and span lengths not exceeding 150 feet and sags not exceeding 15 inches for wires of No. 2 and larger sizes, or 30 inches for wires smaller than No. 2, a six-pin cross-

236. F. Climbing Space on Buckarm Construction—Con.

arm having pin spacing of 14½ inches may be used to provide a 30-inch climbing space on one corner of a junction pole by omitting the pole pins on all arms, and inserting pins midway between the remaining pins so as to give a spacing of 7¼ inches, provided that each conductor on the end of every arm is tied to the same side of its insulator, and that the spacing on the next pole is not less than 14½ inches.

G. Climbing Space for Longitudinal Runs.

The full width of climbing space shall be provided past longitudinal runs and shall extend vertically in the same position from 40 inches below the run to a point 40 inches above (or 60 inches where required by rule 236, E, 1). The width of climbing space shall be measured from the longitudinal run concerned. Longitudinal runs on racks, or supply cables on messengers, are not considered as obstructing the climbing space if all wires concerned are covered by rubber protective equipment or otherwise guarded as an unvarying practice before workmen climb past them. This does not apply where communication conductors are above the longitudinal runs concerned.

Exception 1: If a supply longitudinal run is placed on the side or corner of the pole where climbing space is provided, the width of climbing space shall be measured horizontally from the center of the pole to the nearest supply conductors on crossarms, under the following conditions:

Where the longitudinal run consists of open supply conductors carrying not more than 750 volts between conductors or of effectively grounded continuous metal-sheathed supply cable carrying any voltage, and is supported close to the pole as by brackets, racks, or pins close to the pole, and

Where the nearest supply conductors on crossarms are parallel to and on the same side of

236. G. Climbing Space for Longitudinal Runs—Continued.

the pole as the longitudinal run and within 4 feet above or below the run.

Exception 2: For supply conductors carried on a pole in a position below communication facilities in the manner permitted in rule 220, B, 3, the climbing space need not extend more than 2 feet above such supply space.

H. Climbing Space Past Vertical Conductors.

Vertical runs incased in suitable conduit or other protective covering and securely attached to the surface of the pole or structure are not considered to obstruct the climbing space.

I. Climbing Space Near Ridge-Pin Conductors.

The climbing space specified in rule 236, E, 3 shall be provided above the top crossarm to the ridge-pin conductor but need not be carried past it.

237. WORKING SPACE.

A. Location of Working Spaces.

Working spaces shall be provided on the climbing face of the pole at each side of the climbing space.

B. Dimensions of Working Spaces.

1. ALONG THE CROSSARM.

The working space shall extend from the climbing space to the outmost pin position on the crossarm.

2. PERPENDICULAR TO THE CROSSARM.

The working space shall have the same dimension as the climbing space (see rule 236, E). This dimension shall be measured from the face of the crossarm.

3. VERTICALLY.

The working space shall have a height not less than that required by rule 238 for the vertical separation of line conductors carried at different levels on the same support.

237. Working Space—Continued.

C. Location of Vertical and Lateral Conductors Relative to Working Spaces.

The working spaces shall not be obstructed by vertical or lateral conductors. Such conductors shall be located on the opposite side of the pole from the climbing side or on the climbing side of the pole at a distance from the crossarms at least as great as the width of climbing space required for the highest-voltage conductors concerned. Vertical conductors inclosed in suitable conduit may be attached on the climbing side of the pole.

D. Location of Buckarms Relative to Working Spaces.

Buckarms may be used under any of the following conditions, provided the climbing space is maintained. Climbing space may be obtained as in rule 236, F.

1. STANDARD HEIGHT OF WORKING SPACE.

Lateral working space of the height required by table 11 (rule 238, A, 1) may be provided between the buckarms and adjacent line arms to which conductors on the buckarms are not attached.

Method of meeting requirements. This may be accomplished by increasing the spacing between the line crossarm gains.

2. REDUCED HEIGHT OF WORKING SPACE.

Where no circuits exceeding 8,700 volts between conductors are involved, and the clearances of rule 235, A, 2, (a), (1) and (2) are maintained, buckarms may be placed between line arms having normal spacing, even though such buckarms obstruct the normal working space; provided that a working space of not less than 18 inches in height is maintained either above or below each line arm and each buckarm.

237. D. Location of Buckarms Relative to Working Spaces—Continued.

Exception: The above working space may be reduced to 12 inches if both of the following conditions exist:

Not more than two sets of line arms and buckarms are involved.

Working conditions are rendered safe by providing rubber protective equipment or other suitable devices to insulate and cover line conductors and equipment which are not being worked upon.

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

All line conductors, cables, or equipment located at different levels on the same pole or structure shall have the vertical separations set forth below.

A. Vertical Separation Between Horizontal Crossarms.

Crossarms supporting line conductors shall be spaced in accordance with table 11. Vertical separations between crossarms shall be measured from center to center.

Exception: Where it is established practice to gain poles with lesser crossarm spacings than specified in table 11 such reduced crossarm separations may be employed if all other applicable separations are complied with.

1. BASIC SEPARATIONS.

The separations given in the following table are for crossarms carrying conductors of 0 to 50,000 volts between conductors attached to fixed supports.

834055°—49——7

238. A. Vertical Separation Between Horizontal Crossarms—Continued.

Table 11.—*Vertical separation of crossarms carrying conductors*

[All voltages are between conductors]

Conductors usually at lower levels	Supply conductors; preferably at higher levels: Open wires, 0 to 750 volts; cables, all voltages, having effectively grounded continuous metal sheath or messenger	750 to 8,700 volts	8,700 to 15,000 volts	15,000 to 50,000 volts: Same utility	15,000 to 50,000 volts: Different utilities
	Feet	*Feet*	*Feet*	*Feet*	*Feet*
Communication conductors:					
General	[1 2] 4	4	6	------	6
Used in operation of supply lines	2	[3] 2	4	4	6
Supply conductors:					
0 to 750 volts	2	[4] 2	4	4	6
750 volts to 8,700 volts	--------	[4] 2	4	4	6
8,700 volts to 15,000 volts:					
If worked on alive with long-handled tools, and adjacent circuits are neither killed nor covered with shields or protectors	--------	------	4	4	6
If not worked on alive except when adjacent circuits (either above or below) are killed or covered by shields or protectors, or by the use of long-handled tools not requiring linemen to go between live wires	--------	------	2	[5] 4	[5] 4
Exceeding 15,000 volts, but not exceeding 50,000 volts	--------	------	------	[5] 4	[5] 4

Footnotes on following page.

238. A. Vertical Separation Between Horizontal Crossarms—Continued.

2. INCREASED SEPARATIONS FOR VOLTAGES EXCEEDING 50,000 VOLTS BETWEEN CONDUCTORS.

For voltages greater than 50,000 volts between conductors the clearances of table 11 shall be increased at the rate of 0.4 inch per 1,000 volts of the excess.

B. Vertical Separation Between Line Conductors on Horizontal Crossarms.

Where line conductors are supported on horizontal crossarms spaced as required in rule 238, A, the vertical separation between such conductors shall be not less than the following:

1. WHERE CONDUCTORS ON THE CROSSARM ARE OF THE SAME VOLTAGE CLASSIFICATION.

Under these conditions, the vertical separation required by table 11 may be reduced as follows:

Where crossarm separation required by table 11 is—	Separation between conductors may be reduced to—
2 feet	16 inches.
4 feet	40 inches.
6 feet	60 inches.

[1] Where supply circuits of 550 volts or less, with transmitted power of 3,200 watts or less, are run below communication circuits in accordance with rule 220, B, 3 the clearance may be reduced to 2 feet.

[2] In localities where the practice has been established of placing on jointly used poles, crossarms carrying supply circuits of less than 300 volts to ground and crossarms carrying communcation circuits at a vertical separation less than specified in the table, such existing construction may be continued until the said poles are replaced provided that—

The minimum separation between existing crossarms is not less than 2 feet, and that—

Extensions to the existing construction shall conform to the clearance requirements specified in table 11.

When communication conductors are all in cable, a supply crossarm carrying only wires of not more than 300 volts to ground may be placed at not less than 2 feet above the point of attachment of the cable to the pole provided that—

The nearest supply wire on such crossarm shall be at least 30 inches horizontally from the center of the pole, and that—

The cable be placed so as not otherwise to obstruct the climbing space.

[3] This shall be increased to 4 feet when the communication conductors are carried above supply conductors unless the communication-line-conductor size is that required for grade C supply lines.

[4] Where conductors are operated by different utilities, a minimum vertical spacing of 4 feet is recommended.

[5] These values do not apply to adjacent crossarms carrying phases of the same circuit or circuits.

238. B. Vertical Separation Between Line Conductors on Horizontal Crossarms—Continued.

2. WHERE CONDUCTORS OF DIFFERENT VOLTAGE CLASSIFICATIONS ARE ON SAME CROSSARM.

Under these conditions, the vertical separation between conductors on adjacent crossarms shall be that required by table 11 (rule 238 A, 1) above for the highest voltage classification concerned.

3. CONDUCTORS OF DIFFERENT SAGS ON SAME SUPPORT.

(a) VARIATION IN CLEARANCE. Line conductors supported at different levels on the same structure and strung to different sags shall have vertical spacings at the supporting structures so adjusted that the minimum spacing at any point in the span, at 60° F, no wind, shall not be reduced more than 25 percent from that required at the supports by rule 235, A, 2, (a), (1) and (2) and this rule.

(b) READJUSTMENT OF SAGS. Sags should be readjusted when necessary to accomplish the foregoing, but not reduced sufficiently to conflict with the requirements of rule 261, F, 4. In cases where conductors of different sizes are strung to the same sag for the sake of appearance or to maintain unreduced clearance throughout storms, the chosen sag should be such as will keep the smallest conductor involved in compliance with the sag requirements of rule 261, F, 4.

C. Separation in Any Direction.

The separation in any direction between conductors of the same or different voltage classification when carried on the same structure, but on crossarms which are not horizontal, shall be not less than the values given in table 11 (rule 238, A, 1 and 2) for vertical separation.

238. C. Separation in Any Direction—Continued.

The separation in any direction shall not in any case be less than the horizontal separation specified in rule 235, A, 2, (a), (1) and (2).

D. Vertical Separation for Line Conductors Not Carried on Crossarms.

The vertical separation between conductors not carried on crossarms shall be the same as required in rule 238, B, 1 for conductors on crossarms.

Exception: Conductors on vertical racks or separate brackets other than wood placed vertically meeting the requirements of rule 235, A, 4 may have separations as specified in that rule.

E. Vertical Separation Between Conductors and Non-Current-Carrying Metal Parts of Equipment.

1. EQUIPMENT.

For the purpose of measuring separations under this rule, "equipment" shall be taken to mean noncurrent-carrying metal parts of equipment, including metal supports for cables or conductors, and metal supply-crossarm braces which are attached to metal crossarms or are less than 1 inch from transformer cases or hangers which are not effectively grounded.

2. SEPARATIONS IN GENERAL.

Vertical separations between supply conductors and communication equipment, between communication conductors and supply equipment, and between supply and communication equipment shall be as follows, except as provided in 3, below:

Supply voltage between conductors	Vertical separation
	Inches
0 to 8,700	40
Exceeding 8,700	[a] 60

[a] Transformer cases and associated hangers and supply cables, when effectively grounded, may have a separation of 40 inches.

238\. E. Vertical Separation Between Conductors and Non-Current-Carrying Metal Parts of Equipment—Continued.

3\. SEPARATIONS FOR SPAN WIRES AND BRACKETS.

Span wires or brackets for lamps or trolley contact conductors shall have at least the vertical separations from communication equipment set forth below:

From open communication conductors on cross-arms:

Span wire or bracket above cross-arm	20 inches.[1]
Span wire or bracket below cross-arm	2 feet.
From messenger wires carrying communication cables	1 foot.
From terminal box of communication cables, if practicable	1 foot.[2]
From communication brackets, bridle wire rings, or drive hooks	2 inches

[1] This may be reduced to 12 inches for either span wires or metal parts of lamp brackets at points 40 inches or more from the pole surface.

[2] Where it is not practicable to obtain a clearance of 1 foot from terminal boxes of communication cables, all metal parts of terminals shall have the greatest practicable separation from fixtures or span wires, including all supporting screws and bolts of both attachments.

Exception: If lamp brackets are effectively grounded, these separations do not apply.

239\. CLEARANCES OF VERTICAL AND LATERAL CONDUCTORS FROM OTHER WIRES AND SURFACES ON THE SAME SUPPORT.

Vertical and lateral conductors shall have the clearances and separations required by this rule from other conductors, wires, or surfaces on the same support.

Exception 1: This rule does not prohibit the placing of supply circuits of the same or next voltage classification in the same iron pipe, if each circuit or set of wires be inclosed in a metal sheath.

Exception 2: This rule does not prohibit the placing of paired communication conductors in rings attached directly to the pole or to messenger.

239. Clearances of Vertical and Lateral Conductors From Other Wires and Surfaces on the Same Support—Continued.

Exception 3: This rule does not prohibit placing grounding conductors, neutral conductors which are effectively grounded throughout their length and associated with supply circuits of 0 to 15,000 volts, metal sheathed supply cables or conductors enclosed in conduit, directly on the pole.

Exception 4: This rule does not prohibit placing supply circuits of 550 volts or less and not exceeding 3,200 watts and properly insulated, in the same cable with control circuits with which they are associated.

A. Location of Vertical or Lateral Conductors Relative to Climbing Spaces, Working Spaces, and Pole Steps.

Vertical or lateral conductors shall be located so that they do not obstruct climbing spaces, or lateral working spaces between line conductors at different levels, or interfere with the safe use of existing pole steps.

Exception 1: This rule does not apply to portions of the pole which workmen do not ascend while the conductors in question are alive.

Exception 2: This rule does not apply to vertical runs incased in suitable conduit or other protective covering. (See rule 236, H.)

B. Conductors not in Conduit.

Conductors not incased in conduit shall have the same clearances from conduits as from other surfaces of structures.

C. Mechanical Protection near Ground.

Where within 8 feet of the ground, all vertical conductors, cables, and grounding wires shall be protected by a covering which gives suitable mechanical protection. For grounding wires from light-

239. C. Mechanical Protection near Ground—Continued.
ning arresters, the protective covering specified above shall be of wood molding, or other insulating material giving equivalent protection.

Exception 1: This covering may be omitted from armored cables or cables installed in a grounded metal conduit.

Exception 2: This covering may be omitted from lead-sheathed cables in rural districts.

Exception 3: This covering may be omitted from vertical runs of communication cables or conductors.

Exception 4: This covering may be omitted from grounding wires in rural districts having triple-braid weather-proof covering, or where such grounding wire is one of a number of grounding wires used to provide multiple grounds.

Exception 5: This covering may be omitted from wires which are used solely to protect poles from lightning.

D. Requirements for Vertical and Lateral Supply Conductors on Supply Line Poles or Within Supply Space on Jointly Used Poles.

1. GENERAL CLEARANCES.

In general, clearances shall be not less than the values specified in table 12.

239. D. Requirements for Vertical and Lateral Supply Conductors on Supply Line Poles, etc.—Continued.

TABLE 12.—*General clearances*

[All voltages are between conductors]

Clearance of vertical and lateral conductors	Clearances for highest voltage concerned in the clearance	
	0 to 8,700 volts	Exceeding 8,700 volts, add the following for each 1,000 in excess
	Inches	*Inches*
From surfaces of supports	3	0.25
From span, guy, or messenger wires	6	.4
From line conductors rigidly supported on fixed supports, such conductors being of—		
Same circuit	3	.25
Different circuits	6	.4
From line conductors not rigidly supported on fixed supports	(1)	(1)

[1] The clearances shall be increased beyond the values given above from line conductors on fixed supports (See rule 235, A, 2, (b), and 3, (b)).

2. SPECIAL CASES.

The following requirements apply only to portions of a pole which workmen ascend while the conductors in question are alive:

(a) SIDE-ARM CONSTRUCTION. Vertical conductors in metal-sheathed cables and grounding wires may be run without insulating protection from supply line conductors on poles used only for supply lines and employing side-arm construction on the side of the pole opposite to the line conductors if climbing space is provided on the line-conductor side of the pole.

(b) ON INSULATORS. Vertical and lateral conductors of less than 8,700 volts between con-

239. D. Requirements for Vertical and Lateral Supply Conductors on Supply Line Poles, etc.—Continued.

ductors if on poles used only for supply lines may be run in multiple-conductor cables having suitable substantial insulating covering, if such cable is held taut on standard insulators supported on pins or brackets and is arranged so that the cable is held at a distance of approximately 5 inches from the surface of the pole, and from any pole step.

(c) Conductors to Street Lamps. On poles used only for supply lines, open wires may be run from the supply line arm directly to the head of a street lamp, provided the clearances of table 12 are obtained and the open wires are substantially supported at both ends.

(d) Conductors of Less Than 300 Volts. Vertical or lateral secondary supply conductors of not more than 300 volts to ground may be run in multiple-conductor cable attached directly to the pole surface or to crossarms in such a manner as to avoid abrasion at the point of attachment. Each conductor of such cable which is not effectively grounded, or the entire cable assembly, shall have an insulating covering required for a conductor of at least 1,000 volts.

(e) Other Conditions. If open wire conductors are within 4 feet of the pole, vertical conductors where within a zone of 4 feet above and below such line conductors of not more than 8,700 volts between conductors, or where within a zone 6 feet above and below such line conductors of more than 8,700 volts between conductors, shall be run in one of the following ways:

(1) So as to clear the pole center by not less than 15 inches if the vertical conduc-

239. D. Requirements for Vertical and Lateral Supply Conductors on Supply Line Poles, etc.—Continued.

tors are of 8,700 volts or less between conductors, or 20 inches if more than 8,700 volts;

(2) Enclosed in insulating conduit, or in metal conduit or cable protected by an insulating covering;

(3) Conductors with triple-braid weatherproof or equivalent covering and covered by wood molding.

Methods (2) and (3) apply also to lateral runs and to grounding conductors, except that conductors for grounding lightning-protection wires are not required to be covered within 6 feet above or below circuits of 15,000 volts or more.

E. Requirements for Vertical and Lateral Communication Conductors on Communication Line Poles or Within the Communication Space on Jointly Used Poles.

1. CLEARANCES FROM WIRES.

The clearances and separations of vertical and lateral conductors from other conductors (except those in the same ring run) and from guy, span, or messenger wires shall be 3 inches.

2. CLEARANCES FROM POLE AND CROSSARM SURFACES.

Vertical and lateral insulated communication conductors may be attached directly to a pole or crossarm. They shall have a vertical clearance of at least 40 inches from any supply conductors (other than vertical runs or lamp leads) of 8,700 volts or less between conductors, or 60 inches if more than 8,700 volts between conductors.

Exception: These clearances do not apply where the supply circuits involved are those carried in the manner specified in rule 220, B, 3.

239. Clearances of Vertical and Lateral Conductors From Other Wires and Surfaces on the Same Support—Continued.

F. Requirements for Vertical Supply Conductors Passing Through Communication Space on Jointly Used Poles.

Vertical supply conductors, including grounding wires, which pass through communication line space on jointly used poles shall be installed as follows:

1. METAL-SHEATHED SUPPLY CABLES.

Metal-sheathed supply cables shall be covered as follows:

(a) EXTENT OF COVERING. Covering shall extend from the lowest points of such cables up to 40 inches above the highest communication conductors.

(b) NATURE OF COVERING. The covering shall consist of wood molding or other suitable insulating material at points higher than 8 feet above the ground.

Exception 1: Metal pipe may be used throughout, under the following conditions:

On poles where there are no trolley attachments and the metal pipe is effectively grounded, no insulating covering is required.

On poles where there are trolley attachments or where the metal pipe is not effectively grounded, the pipe shall be covered with wood molding or other suitable insulating material from a point six feet below the lowest communication wire or trolley attachment to a point 40 inches above the highest communication wire or trolley attachment.

Exception 2: No insulating covering is required over supply secondary multi-

239. F. Requirements for Vertical Supply Conductors Passing Through Communication Space on Jointly Used Poles—Continued.

conductor cables attached directly to the pole surface in accordance with the requirements of rule 239, F, 2 (c).

Exception 3: Where there are no trolley attachments on the pole, no insulating covering is required over supply cables having effectively grounded lead sheath, or supply cables having effectively grounded metal sheath of other types where mutually agreed to by the parties concerned.

2. SUPPLY CONDUCTORS.

Supply conductors shall be installed in one of the following ways:

(a) IN CONDUIT. Conductors of all voltages may be inclosed in the same way and to the same extent as required in 1 above for metal-sheathed cables.

(b) ON PINS AND INSULATORS. Vertical and lateral conductors of street-lighting circuits and service leads of less than 750 volts to ground may be run on the street side of the pole in multiple-conductor cable having suitable substantial insulating covering if such cable is held taut on standard insulators supported on pins or brackets and arranged so that the cable shall be held at a distance of approximately 5 inches away from the surface of the pole or from any pole steps.

(c) INSTALLED ON THE POLE SURFACE. Secondary supply conductors of not more than 300 volts to ground may be run in multiple-conductor cables attached directly to the pole surface in such a manner as to avoid abrasion at the points of attachment. In

239. F. Requirements for Vertical Supply Conductors Passing Through Communication Space on Jointly Used Poles—Continued.

the case of aerial services, the point where such cables leave the pole shall be at least 40 inches above the highest, or 40 inches below the lowest, communication attachment. Each conductor of such cable which is not effectively grounded shall be insulated for a potential of at least 1,000 volts.

(d) Suspended From Supply Crossarm. Lamp leads of street lighting circuits may be run from supply crossarms directly to a street lamp bracket or luminaire under the following conditions:

(1) The vertical run shall consist of paired wires or multiple-conductor cable securely attached at both ends to suitable brackets and insulators.

(2) The vertical run shall be held taut at least 40 inches from the surface of the pole (through the communication space), at least 12 inches beyond the end of any communication crossarm by which it passes, and at least 6 inches from communication drop wires.

(3) Insulators attached to lamp brackets for supporting the vertical run shall be capable of meeting, in the position in which they are installed, the same flashover requirements as the luminaire insulators.

(4) Each conductor of the vertical run shall be No. 10 AWG or larger.

3. SUPPLY GROUNDING WIRES.

Supply grounding wires shall be covered with wood molding or other suitable insulating cover-

239. F. Requirements for Vertical Supply Conductors Passing Through Communication Space on Jointly Used Poles—Continued.

ing to the extent required for metal-sheathed cables in 1 above.

Exception: If there are no trolley attachments on the pole, insulating covering is not required for a grounding conductor which is metallically connected to a conductor which forms part of an effective grounding system.

4. SEPARATION FROM THROUGH BOLTS.

Vertical runs of supply conductors shall be separated from the ends of through bolts associated with communication line equipment by one-eighth of the circumference of the pole where practicable, but in no case less than 2 inches.

G. Requirements for Vertical Communication Conductors Passing Through Supply Space on Jointly Used Poles.

All vertical runs of communication conductors passing through supply space shall be installed as follows:

1. METAL-SHEATHED COMMUNICATION CABLES.

Vertical runs of metal-sheath communication cables shall be covered with wood molding, or other suitable insulating material, where they pass trolley feeders or other supply-line conductors. This insulating covering shall extend from a point 40 inches above the highest trolley feeders, or other supply conductors, to a point 6 feet below the lowest trolley feeders or other supply conductors, but need not extend below the top of any mechanical protection which may be provided near the ground.

Exception: Communication cables may be run vertically on the pole through space occupied by railroad-signal supply circuits in the lower position, as permitted in rule 220, B, 3, without insulating covering within the supply space.

239. G. Requirements for Vertical Communication Conductors Passing Through Supply Space on Jointly Used Poles—Continued.

2. COMMUNICATION CONDUCTORS.

Vertical runs of insulated communication conductors shall be covered with wood molding, or other suitable insulating material, to the extent required for metal-sheathed communication cables in 1 above, where such conductors pass trolley feeders or other supply conductors.

Exception: Communication conductors may be run vertically on the pole through space occupied by railroad-signal supply circuits in the lower position, as permitted in rule 220, B, 3, without insulating covering within the supply space.

3. COMMUNICATION GROUNDING CONDUCTORS.

Vertical communication grounding conductors shall be covered with wood molding or other insulating material between points at least 6 feet below and 40 inches above any trolley feeders or other supply line conductors by which they pass.

Exception: Communication grounding conductors may be run vertically on the pole through space occupied by railroad-signal supply circuits in the lower position, as permitted in rule 220, B, 3, without insulating covering within the supply space.

4. SEPARATION FROM THROUGH BOLTS.

Vertical runs of communication conductors shall be separated from the ends of through bolts associated with supply-line equipment by one-eighth of the circumference of the pole where practicable, but in no case less than 2 inches.

240. General.

For the purposes of section 26, "Strength requirements", and section 27, "Line insulators", conductors and their supporting structures are classified under the grades specified in this section on the basis of the relative hazard existing.

241. Application of Grades of Construction to Different Situations.

A. Supply Cables.

For the purposes of these rules, supply cables are divided into two classes as follows:

1. SPECIALLY INSTALLED CABLES.

In this class are included metal-sheathed supply cables installed in accordance with rule 261, G, 1.

Note: Such cables are sometimes permitted to have a lower grade of construction than open-wire supply conductors of the same voltage.

2. OTHER CABLES.

In this class are included all other supply cables.

Note: Such cables are required to have the same grade of construction as open-wire supply conductors of the same voltage.

B. Two or More Conditions.

In any case where two or more conditions affecting the grade of construction exist, the grade of construction used shall be the highest one required by any of the conditions.

C. Order of Grades.

For supply and communication conductors and supporting structures, the relative order of grades is B, C, and N, grade B being the highest. Where grades D and N are specified for communication lines, grade D is the higher.

Note: Grade D cannot be directly compared with grades B and C, but rule 241, D, 3, (c) provides for cases where these two conditions are present.

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241. Application of Grades of Construction, etc.—Con.

D. At Crossings.

1. GRADE OF UPPER LINE.

Conductors and supporting structures of a line crossing over another line shall have the grade of construction specified in rules 241, D, 3; 242, and 243.

2. GRADE OF LOWER LINE.

Conductors and supporting structures of a line crossing under another line need only have the grades of construction which would be required if the line at the higher level were not there.

3. MULTIPLE CROSSINGS.

(*a*) WHERE A LINE CROSSES IN ONE SPAN OVER TWO OTHER LINES. The grade of construction of the uppermost line shall be not less than the highest grade which would be required of either one of the lower lines if it crossed the other lower line.

Example: If a 2,300-volt line crosses in the same span over a communication line and a direct-current trolley contact conductor of more than 750 volts, the 2,300-volt line is required to comply with grade B construction at the crossing.

This is a double crossing and introduces a greater hazard than where the upper supply line crosses the communication line only.

(*b*) WHERE ONE LINE CROSSES OVER A SPAN IN ANOTHER LINE, WHICH SPAN IS IN TURN INVOLVED IN A SECOND CROSSING. The grade of construction for the highest line shall be not less than that required for the next lower line.

Exception: This requirement does not apply when the two upper lines are of

241\. D. At Crossings—Continued.

such a nature and have such circuit protection that the danger of causing a break in the lower of these two lines by mechanical or electrical contact is eliminated.

(c) Where Communication Conductors Cross Over Supply Conductors and Railroad Tracks in the Same Span. The grades of construction shall be in accordance with table 13.

Recommendation: It is recommended that the placing of communication conductors above supply conductors at crossings, conflicts, or on jointly used poles, be avoided unless the supply conductors are trolley contact conductors and their associated feeders.

Table 13.—*Grades of construction for communication conductors crossing over railroad tracks and supply lines*

When crossing over—	Communication conductor grades
Railroad tracks and supply lines of 0 to 750 volts to ground, or specially installed supply cables of all voltages	D
Railroad tracks and supply lines exceeding 750 volts to ground	B

E. Conflicts.

1\. HOW DETERMINED.

Where two lines are adjacent (except at crossing spans) the distance between them and the relative heights above ground of poles and of conductors on each line determine whether conflict exists, and, if so, whether the conflict is a structure conflict (see definition) or a conductor conflict (see definition), or both.

241. E. Conflicts—Continued.

2. CONDUCTOR CONFLICT.

At conductor conflicts, the grade of construction of the conflicting conductor shall be as required by rules 241, D, 3, and 242.

3. STRUCTURE CONFLICT.

At structure conflicts, the grade of construction of the conflicting structure shall be as required by rule 243.

242. Grades of Construction for Conductors.

The grades of construction required for conductors of all classes in different stituations are given in tables 14 and 15. For the purpose of these tables certain classes of circuits are treated as follows:

A. Status of Constant-Current Circuits.

The grade of construction for a constant-current supply circuit involved with a communication circuit and not in specially installed cable shall be based on either its current rating or on the open-circuit voltage rating of the transformer supplying such circuit, as set forth in tables 14 and 15. In all other cases the grade of construction for a constant-current circuit shall be based on its nominal full-load voltage.

B. Status of Railway Feeders and Trolley Contact Conductors.

In determining grades of construction where railway feeders and trolley-contact conductors are involved, they shall be considered as other supply conductors of the same voltage.

Exception: Direct-current trolley circuits exceeding 750 volts to ground where crossing over, conflicting with, or on jointly used poles with and above communication circuits, shall have the grades of construction specified in table 14 for direct-current railway feeders.

242. Grades of Construction for Conductors—Continued.

C. Status of Communication Circuits Used Exclusively in the Operation of Supply Lines.

In determining grades of construction where communication circuits used exclusively in the operation of supply lines are concerned, they shall be considered as ordinary communication circuits when run as such (see rule 288, A, 3) and as supply circuits when run as such (see rule 288, A, 4).

Exception: Communication circuits located below supply circuits with which they are used shall not require such supply circuits to meet any rules for grade of construction other than that the sizes of such supply conductors shall be not less than required for grade C (see rule 261, F, 2).

D. Status of Fire-Alarm Conductors.

In determining grades of construction where fire-alarm conductors are concerned, they shall be considered as other communication circuits.

Exception: Fire-alarm conductors shall always meet grade D where the span length is from 0 to 150 feet, and grade C where the span length exceeds 150 feet.

E. Status of Neutral Conductors of Supply Circuits.

Supply-circuit neutral conductors, which are effectively grounded throughout their length and are not located above supply conductors of more than 750 volts to ground, shall have the same grade of construction as supply conductors of not more than 750 volts to ground, except that they need not meet any insulation requirements. Other neutral conductors shall have the same grade of construction as the phase conductors of the supply circuits with which they are associated.

242. E. Status of Neutral Conductors of Supply Circuits—Continued.

TABLE 15.—*Grades of construction for communication conductors alone, or in upper position at crossings, at conflicts, or on joint poles*

[All voltages are to ground, which, for ungrounded circuits, means the highest voltage between any two conductors.]

Conductors, tracks, and rights-of-way at lower levels ↓ / Communication conductors at higher levels [1] →			Communication conductors, rural or urban, open or cable, including communication conductors run as such, but used exclusively in the operation of supply lines: Major	Minor
Fenced rights-of-way			N	N
Elsewhere than on fenced rights-of-way			N	N
Railroad tracks—main or minor			D	D
Street-railway tracks having no overhead-contact wire			N	N
Constant-potential supply conductors [2]	0 to 750 volts	Open or cable	N	N
	750 to 2,900 volts	do	C	C
	Exceeding 2,900 volts	Open	B	C
		Cable	C	C
Constant-current supply conductors.[2]	0 to 7.5 amperes	Open [3]	C	C
	Exceeding 7.5 amperes	do.[3]	[4] B	C
Direct-current railway feeders.[2]	0 to 750 volts	Open or cable	N	N
	Exceeding 750 volts	do	B	C
Trolley-contact conductors.	0 to 750 volts	ac or dc	C	C
	Exceeding 750 volts	ac	[5] B or C	[5] B or C
		dc	B	C
Communication conductors, open or cable, used exclusively in the operation of supply lines			B, C, or N [6]	
Communication conductors, open or cable, urban or rural, major or minor			N	

[1] It is recommended that the placing of communication conductors above supply conductors at crossings, conflicts, or on jointly used poles be avoided, unless the supply conductors are trolley-contact conductors and their associated feeders.

[2] The words "open" and "cable" appearing in the headings have the following meaning as applied to supply conductors: "Cable" means the specially installed cables described in rule 241, A, 1. "Open" means open wire and also supply cables not specially installed.

[3] Where constant-current circuits are in specially installed cable, they are considered on the basis of the nominal full-load voltage.

[4] Grade C construction may be used if the open-circuit voltage of the transformer supplying the circuit does not exceed 2,900 volts.

[5] See rule 242, B.

[6] See rule 242, C.

243. Grades of Supporting Structures.

A. Poles or Towers.

The grade of construction shall be that required for the highest grade of conductors supported.

Exception 1: The grade of construction of jointly used poles, or poles used only by communication lines, need not be increased merely because of the fact that communication wires carried on such poles cross over trolley contact conductors of 0 to 750 volts to ground.

Exception 2: Poles carrying grade C or D fire-alarm conductors, where alone, or where concerned only with other communication conductors, need meet only the requirements of grade N.

Exception 3: Poles carrying supply service loops of 0 to 750 volts to ground shall have at least the grade of construction required for supply line conductors of the same voltage.

Exception 4: Where communication lines cross over supply conductors and a railroad in the same span and grade B is required by rule 241, D, 3, (c) for the communication conductors, due to the presence of railroad tracks, the grade of the poles or towers shall be D.

Exception 5: At structure conflicts, even though no conductor conflict exists, the grade of construction which would be required by rule 242, if the conductors were in conflict, shall be applied to the pole or tower.

Note: This requirement may result in a higher grade of construction for the pole or tower than for the conductors carried thereon.

Exception 6: In the case where a structure conflict does not exist, but any conductor is in conductor conflict, the grade of construction of the pole or tower is not required to meet the conductor grade due to the conductor conflict.

243. Grades of Supporting Structures—Continued.

B. Crossarms.

The grade of construction shall be that required for the highest grade of conductors carried by the crossarm concerned.

Exception 1: The grade of construction of crossarms carrying only communication conductors need not be increased merely because of the fact that such conductors cross over trolley-contact conductors of 0 to 750 volts to ground.

Exception 2: Crossarms carrying grade C or D fire-alarm conductors, where alone or where concerned with other communication conductors, need meet only the requirements for grade N.

Exception 3: Crossarms carrying supply service loops of 0 to 750 volts to ground shall have at least the grade of construction required for supply line conductors of the same voltage.

Exception 4: Where communication lines cross over supply conductors and a railroad in the same span and grade B is required by rule 241, D, 3, (c) for the communication conductors due to the presence of railroad tracks, the grade of the crossarm shall be D.

C. Pins, Insulators, and Conductor Fastenings.

The grade of construction shall be that required for the conductor concerned.

Exception 1: The grade of construction of pins, insulators, and conductor fastenings carrying only communication conductors need not be increased merely because of the fact that such conductors cross over trolley-contact conductors of 0 to 750 volts to ground.

Exception 2: In the case of grade C or D fire-alarm conductors where alone, or where concerned only with other communication conductors, pins,

243. C. Pins, Insulators, and Conductor Fastenings—Con.

insulators, and conductor fastenings need meet only the requirements for grade N.

Exception 3: In the case of supply service loops of 0 to 750 volts to ground, pins, insulators, and conductor fastenings shall have at least the same grade of construction as required for supply-line conductors of the same voltage.

Exception 4: Where communication lines cross over supply conductors and a railroad in the same span, and grade B is required by rule 241, D, 3, (c) for the communication conductors due to the presence of railroad tracks, the grade of pins, insulators, and conductor fastenings shall be D.

Exception 5: In case communication conductors are required to meet grade B or C, the insulators need meet only the requirements for mechanical strength for these grades.

SEC. 25. LOADING FOR GRADES B, C, AND D

250. General Loading Map.

Three general degrees of loading due to weather conditions are recognized and are designated as heavy, medium, and light loading. The map in figure 1 shows the districts in the United States in which these loadings are normally applicable. It is recognized that loadings in certain areas in each of the loading districts are greater, and in some cases may be less, than those specified for the districts. It is expected that detailed districting will be carried out by state administrative authorities, which will delineate, as far as practicable, such areas. In the absence of such detailed districting, however, no reduction in the loadings specified in this code shall be made without approval of the administrative authority.

Note: The localities in the different groups are classed according to the relative prevalence of high wind velocity and thickness of ice which accumulates on wires, light loading being,

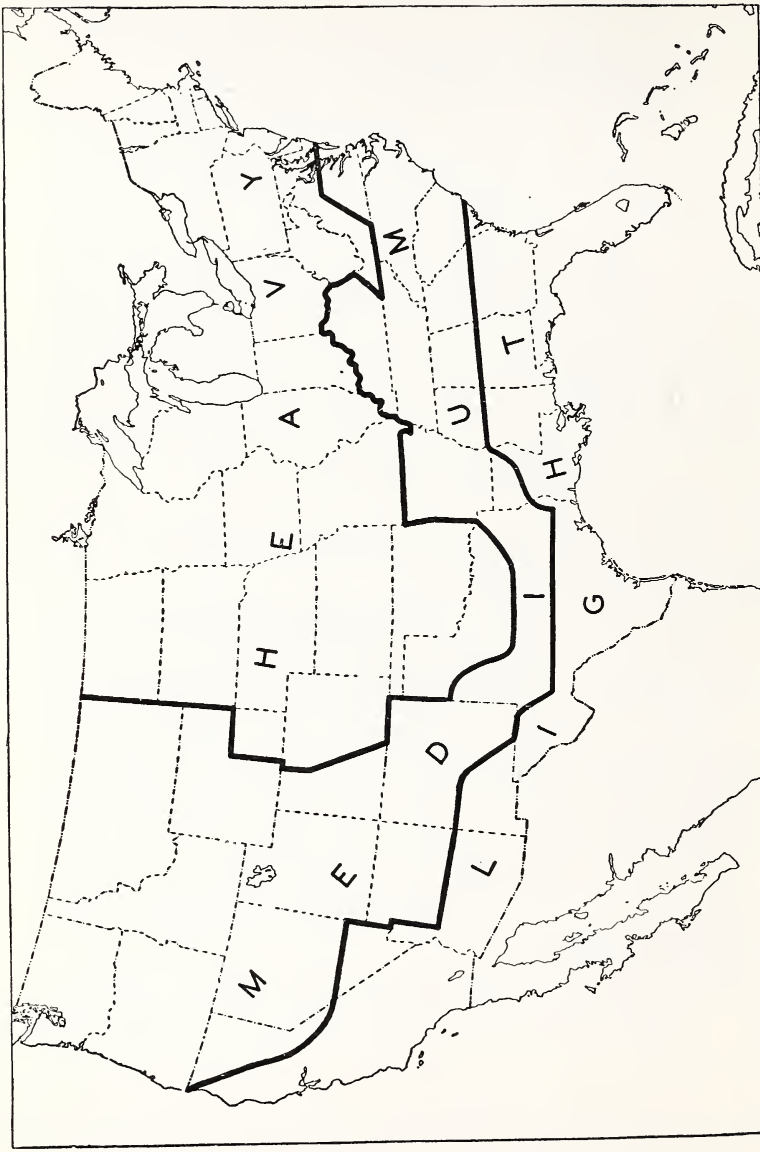

FIGURE 1.—*General loading map showing territorial division of the United States with respect to loading of overhead lines.*

250. General Loading Map—Continued.

in general, for places where little, if any, ice ever accumulates on wires.

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

251. Conductor Loading.

The loading on conductors shall be assumed to be the resultant loading per foot equivalent to the vertical load per foot of the conductor, ice-covered where specified, combined with the transverse loading per foot due to a transverse, horizontal wind pressure upon the projected area of the conductor, ice-covered where specified, to which equivalent resultant shall be added a constant. In the tabulation below are the values for ice, wind, temperature, and constants which shall be used to determine the conductor loading.

	Loading district		
	Heavy	Medium	Light
Radial thickness of ice (in.)	0. 50	0. 25	0
Horizontal wind pressure in pounds per square foot	4	4	9
Temperature (° F)	0	+15	+30
Constant to be added to the resultant in pounds per foot:			
For bare conductors of copper, steel, copper alloy, copper-covered steel, and combinations thereof	0. 29	0. 19	0. 05
For bare conductors of aluminum (with or without steel reinforcement)	. 31	. 22	. 05
For weather-proof and similar covered conductors (all materials)	. 31	. 22	. 05

251. Conductor Loading—Continued.

Note: Since heavy ice does not often form on conductors in a heavy wind, the transverse loading assumed is deemed sufficient for the purpose, but is not sufficient to represent the vertical (or combined) load which is imposed on conductors by the heavy deposits of ice which frequently form in comparatively still air. In order to apply a total loading to conductors representing more nearly the conditions encountered in practice, constants have been added to the conductor loading which make no substantial change in the conductor loading specified in the fourth edition of this code.

Where cables are concerned, the specified loadings shall be applied to both cable and messenger.

In applying loadings to bare stranded conductors, the coating of ice shall be considered as a hollow cylinder touching the outer strands.

252. Loads Upon Line Supports.

A. Assumed Vertical Loading.

The vertical loads upon poles, towers, foundations, crossarms, pins, insulators, and conductor fastenings shall be their own weight plus the superimposed weight which they support, including all wires and cables, ice-coated in heavy and medium loading districts, together with the effect of any difference in elevation of supports. The radial thickness of ice shall be computed only upon wires, cables, and messengers, and shall be taken as the following:

Heavy loading district (H), 0.50 inch of ice.
Medium loading district (M), 0.25 inch of ice.
Light loading district (L), no ice.

Ice is assumed to weigh 57 pounds per cubic foot.

Note: The weight of ice upon supports is ignored for the sake of simplicity.

B. Assumed Transverse Loading.

In computing the stresses in poles, towers, and side guys the loading shall be taken as one of the following according to climatic conditions of the locality concerned.

252. B. Assumed Transverse Loading—Continued.

1. HEAVY LOADING (H).

A horizontal wind pressure, at right angles to the direction of the line, of 4 pounds per square foot upon the projected area of cylindrical surfaces of all supported conductors and messengers, when covered with a layer of ice 0.5 inch in radial thickness and on surfaces of the poles and towers without ice covering, shall be called heavy loading. (See 4 and 5 following.)

For supporting structures carrying more than 10 wires, not including cables supported by messengers, where the pin spacing does not exceed 15 inches, the transverse load shall be calculated on two-thirds of the total number of such wires with a minimum of 10 wires.

2. MEDIUM LOADING (M).

A horizontal wind pressure at right angles to the direction of the line, of 4 pounds per square foot upon the projected area of cylindrical surfaces of all supported conductors and messengers when covered with a layer of ice 0.25 inch in radial thickness and on the surfaces of the poles and towers without ice covering, shall be called medium loading. (See 4 and 5 following.)

For supporting structures carrying more than 10 wires, not including cables supported by messengers, where the pin spacing does not exceed 15 inches, the transverse load shall be calculated on two-thirds of the total number of such wires with a minimum of 10 wires.

3. LIGHT LOADING (L).

A horizontal wind pressure at right angles to the direction of the line of 9 pounds per square foot upon the projected area of cylindrical surfaces of all supported conductors and messengers, poles and towers without ice covering, shall be called light loading. (See 4 and 5 following.)

252. B. Assumed Transverse Loading—Continued.

4. TROLLEY-CONTACT CONDUCTORS.

When a trolley-contact conductor is supported on a pole it shall be included in the computation of the transverse load on the structure.

5. FLAT SURFACES.

For flat surfaces the assumed unit wind pressure shall be increased by 60 percent. Where latticed structures are concerned, the actual exposed area of one lateral face shall be increased by 50 percent to allow for the pressure on the opposite face; this total, however, need not exceed the pressure which would occur on a solid structure of the same outside dimensions. The results obtained by more exact calculations may be substituted for the values obtained by this simple rule.

6. AT ANGLES (COMBINED LONGITUDINAL AND TRANSVERSE LOADING).

Where a change in direction of wires occurs, the loading upon the structure, including guys, shall be assumed to be a resultant load equal to the vector sum of the transverse wind load given in 1, 2, or 3 above and the resultant load imposed by the wires due to their change in direction. In obtaining these loadings, a wind direction shall be assumed which will give the maximum resultant load, proper reduction being made in loading to account for the reduced wind pressure on the wires resulting from the angularity of the application of the wind to the wires.

C. Assumed Longitudinal Loading.

1. CHANGE IN GRADE OF CONSTRUCTION.

The longitudinal loading upon supporting structures, including poles, towers, and guys at ends of sections required to be of grade B construction, when located in lines of lower than grade B construction, shall be taken as an unbalanced pull in

252. C. Assumed Longitudinal Loading—Continued.

the direction of the higher grade section equal to the pull of two-thirds of the conductors supported thereon which are smaller than No. 2 AWG, the conductor loading to be that given in rule 251, and such two-thirds of the conductors being selected so as to produce the maximum stress in the supports.

If the application of the above results in a fractional part of a conductor, the nearest whole number shall be used. In no case shall the assumed unbalanced pull on the supporting structure be less than the maximum loaded tension in any two of the conductors carried (including overhead ground wires), such two conductors being selected so as to produce the maximum stress in the supports.

2. JOINTLY USED POLES AT CROSSINGS OVER RAILROADS OR COMMUNICATION LINES.

Where a joint line crosses over a railroad or a communication line and grade B is required for the crossing span, the tension in the communication conductors of the joint line may be considered as limited to one-half their breaking strength, provided they are smaller than No. 8 Stl. WG, if of steel, or No. 6 AWG, if of copper, regardless of how small the initial sags of the communication conductors at 60° F.

3. DEAD-ENDS.

The longitudinal loading upon supporting structures shall be taken as an unbalanced pull equal to the tensions of all conductors and messengers (including overhead ground wires), under the conditions of conductor loading specified in rule 251.

4. COMMUNICATION CONDUCTORS ON UNGUYED SUPPORTS AT RAILROAD CROSSINGS

The longitudinal loading shall be assumed equal to an unbalanced pull in the direction of the

252. C. Assumed Longitudinal Loading—Continued.

crossing of all open-wire conductors supported, the pull of each conductor being taken as 50 percent of its ultimate strength in the heavy loading district, 33⅓ percent in the medium loading district, and 22¼ percent in the light loading district.

D. Average Span Lengths.

1. GENERAL.

The calculated transverse loads upon poles, towers, and crossarms, except as provided in 2 below, shall be based upon the average span length of a section of line that is reasonably uniform as to height, number of wires, grade, and span length. In no case shall the average value taken be less than 75 percent or more than 125 percent of the actual average of the two spans adjacent to the structure concerned.

2. CROSSINGS.

In the case of crossings over railroads or communication lines (other than minor communication lines) the actual lengths of the two spans adjacent to the two structures concerned shall be used.

E. Simultaneous Application of Loads.

1. When calculating transverse strength, the assumed transverse and vertical loads shall be taken as acting simultaneously.
2. In calculating longitudinal strength, the assumed longitudinal loads shall be taken without consideration of the vertical or transverse loads.

SEC. 26. STRENGTH REQUIREMENTS

260. PRELIMINARY ASSUMPTIONS.

It is recognized that deformation, deflection, or displacement of parts of the structure will, in some cases, change the effects of the loads assumed. In the calculation of stresses, however, no allowance shall be made for such

260. Preliminary Assumptions—Continued.

deformation, deflection, or displacement of supporting structures (including poles, towers, guys, crossarms, pins, conductor fastenings, and suspension insulators) unless the methods used to evaluate them have been approved by the administrative authority.

261. Grades B and C Construction.

A. Poles and Towers.

The strength requirements for poles and towers may be met by the structures alone or with the aid of guys or braces.

1. AVERAGE STRENGTH OF THREE POLES.

A pole (single-base structure) not individually meeting the transverse strength requirements will be permitted when reinforced by a stronger pole on each side, if the average strength of the three poles meets the transverse strength requirements, and the weak pole has not less than 75 percent of the required strength.

An extra pole inserted in a normal span for the purpose of supporting a service loop may be ignored, if desired, in the calculation of the strength of the line.

Exception: In the case of crossings over railroads or communication lines (other than minor communication lines), the actual strengths of the crossing poles shall be used.

2. REINFORCED-CONCRETE POLES.

Reinforced-concrete poles shall be of such material and dimensions as to withstand, for vertical and transverse strength, the loads assumed in rules 252, A and B, and for longitudinal strength the loads in rule 252, C, without exceeding the following percentages of their ultimate strength at the ground line for unguyed poles, or at the point of guy attachment for guyed poles. (Where guys are used, see rule 261, C.)

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261. A. Poles and Towers—Continued.

	Percentages of ultimate strength for reinforced-concrete poles	
	Grade B	Grade C
For transverse strength (when installed)	25	37. 5
For longitudinal strength (at all times):		
In general	100	No requirement.
At dead-ends	50	75. 0

3. STEEL SUPPORTING STRUCTURES.

In the design of steel structures, the term "overload capacity factor" referred to in table 16 is to be interpreted in such a manner that the completed structure, if tested, shall support without permanent deflection the maximum loading to which it will be subjected as specified in section 25, multiplied by the factors given in table 16. The absence of permanent set on the structure indicates that no part has been stressed beyond the yield point. Allowance should be made for bolt slip.

Steel supports, steel towers, and metal poles shall be designed and constructed so as to meet the following requirements:

(a) VERTICAL AND TRANSVERSE STRENGTH. The completed structure shall be so designed and of sufficient strength as to provide overload capacity factors specified in table 16 under the vertical and transverse loading specified in rule 252, A and B, 1 to 5, inclusive.

(b) LONGITUDINAL STRENGTH.

Grade B. The completed structure shall be so designed and of sufficient strength as to provide overload capacity factors

261. A. Poles and Towers—Continued.

specified in table 16 under the longitudinal loading specified in rule 252, C.

Grade C. No longitudinal strength requirements except at dead-ends.

(c) Minimum Strength. Steel structures shall have strength sufficient to withstand, with an overload capacity factor of 1.1, a transverse load on the structures without conductors, equal to six times the specified wind pressure.

(d) Strength at Angles in a Line. At an angle in a line having supports of steel poles or towers, the strength of the support shall be sufficient to withstand a combination of the transverse and longitudinal loadings specified in rule 252, B, 6. For grade B the transverse load shall be multiplied by 1.54, and for grade C by 2.00, before combining with the load arising from change in direction of conductors. The allowable overload capacity factor at dead-ends given in table 16 shall be provided for the total load thus computed.

Table 16.—*Minimum overload capacity factors of completed structures*

[Based on yield point of steel]

	Overload capacity factors	
	Grade B	Grade C
Vertical strength	1.27	1.10
Transverse strength	2.54	2.20
Longitudinal strength:		
At crossings—		
In general	1.10	No requirement.
At dead-ends	1.65	1.10
Elsewhere—		
In general	1.00	No requirement.
At dead-ends	1.65	1.10

261. A. Poles and Towers—Continued.

(e) Thickness of Steel. The thickness of metal in members of steel poles or towers shall be not less than the following:

Table 17.—*Thickness of steel*

	Thickness of main members of crossarms and legs	Thickness of other members
	Inches	*Inches*
For localities where experience has shown deterioration of protective covering is rapid	1/4	3/16
For other localities	3/16	1/8

(f) Unsupported Length of Compression Members. The ratio of L, the unsupported length of a compression member, to R, the least radius of gyration of the member, shall not exceed the following (these figures do not apply to the complete structure):

Table 18.—*L/R for compression members*

Kind of compression member	L/R
Leg members	150
Other members having figured stresses	200
Secondary members without figured stresses	250

(g) General Construction Features. Steel poles or towers, including parts of footings above ground, shall be constructed so that all parts are accessible for inspection, cleaning, and painting, and so that pockets are not formed in which water can collect.

Recommendation: Unless sample structures, or similar ones, have been tested to assure the compliance of structures in any line with these

261. A. Poles and Towers—Continued.

requirements, it is recommended that structures be designed to have a computed strength at least 10 percent greater than that required by these rules.

(h) PROTECTIVE COVERING OR TREATMENT. All iron or steel poles, towers, or supporting structures shall be protected by galvanizing, painting, or other treatment which will effectively retard corrosion. Such protective covering shall be adequately maintained.

4. WOOD POLES.

Wood poles shall be of such material and dimensions as to meet the following requirements (where guys are used, see rule 261, C):

(a) TRANSVERSE STRENGTH. Wood poles shall withstand the transverse and vertical loads assumed in rule 252, A and B, 1 to 4, inclusive, without exceeding at the ground line for unguyed poles, or at the point of guy attachment for guyed poles, the appropriate allowable percentages of their ultimate stress given in table 20.

(b) LONGITUDINAL AND DEAD-END STRENGTH. The longitudinal and dead-end strength of wood poles shall be such that they will withstand the appropriate longitudinal loading specified in rule 252, C, without exceeding, at the ground line for unguyed poles or at the point of guy attachment for guyed poles, the following percentages of the applicable ultimate fiber stress given in table 19.

261. A. Poles and Towers—Continued.

	Percentages of ultimate fiber stress for wood poles	
	Grade B	Grade C
Longitudinal:		
When installed	[1] 75	No requirement.
At replacement	100	Do.
Dead-ends:		
When installed	[1] 50	[1] 75
At replacement	75	100

[1] Where supply lines alone are involved and built for a fixed period of temporary service not exceeding 5 years the prescribed percentage of fiber stress at installation may be increased, provided the percentage of ultimate fiber stress required at replacement is not exceeded during the life of the line.

Exception 1: At a Grade B crossing, in a straight section of line, wood poles of approximately round cross section, complying with the transverse strength requirements of rule 261, A, 4 (a), without the use of transverse guys, shall be considered as having the required longitudinal strength. This exception does not modify the requirements of this rule for dead-ends.

Exception 2: At a grade B crossing of a supply line over a highway and a communication line in the same span, where there is an angle in the supply line, wood poles of approximately round cross section shall be considered as having the required longitudinal strength if all of the following conditions obtain:

1. The angle is not over 20 degrees.
2. The corner pole is guyed in the plane of the resultant of the conductor tensions on both sides of the corner pole; the tension in this guy not to exceed 50 percent of its ultimate strength under the loading of rule 252, B, 6.

261. A. Poles and Towers—Continued.

3. The corner pole has sufficient strength to withstand, without guys, the transverse loading of rule 252, B, 1, 2 or 3, which would exist if there were no angle at that pole, without exceeding 25 percent of its ultimate stress when installed, or 37½ percent at replacement.

(c) Ultimate Fiber Stress. Different kinds of wood poles are considered as having the ultimate fiber stresses given in table 19.

Table 19.—*Ultimate fiber stresses of wood poles*

Kind of wood	Ultimate fiber stress
	lb/sq in.
Creosoted southern pine	7, 400
Douglas fir	7, 400
Lodgepole pine	6, 600
Chestnut	6, 000
Western red cedar	5, 600
Cypress	5, 000
Northern white cedar	3, 600
Redwood	3, 600

When values for ultimate stresses of cypress and redwood have been approved as standard by the American Standards Association, such values shall be used in place of those given above.

(d) Allowable Percentages of Ultimate Stress. The allowable percentages of ultimate stress of treated and untreated poles to withstand vertical and transverse loads are given in table 20, except as modified in the following paragraph.

At crossings where grade B construction is required, if the supply line is not maintained throughout (or between and including the nearest guyed points on each side of the crossing) so that the poles will not be stressed at any time in excess of 50 percent

261. A. Poles and Towers—Continued.

of their ultimate stress under the transverse loading assumed in rule 252, B, the crossing poles, if unguyed, shall be of such strength that they will withstand the transverse loading assumptions of rule 252 B, 1, 2, or 3, without exceeding 16⅔ percent of their ultimate stress at installation or 25 percent at replacement. If the crossing poles are side guyed, such guys shall meet the requirements of rule 261, C, 5.

TABLE 20.—*Allowable percentages of ultimate stress for treated or untreated wood poles under vertical and transverse loading*

	When installed	At replacement
Grade B	25.0	37.5
Grade C:		
At crossings	37.5	75.0
Elsewhere	50.0	75.0

(e) FREEDOM FROM DEFECTS. Wood poles shall be of suitable and selected timber free from observable defects that would decrease their strength or durability.

(f) MINIMUM POLE SIZES. Wood poles shall have a nominal top circumference of not less than 15 inches.

(g) SPLICED AND STUB-REINFORCED POLES. Spliced poles shall not be used at crossings, conflicts, or joint-use sections requiring grades B or C construction.

Except at crossings over major railroad tracks, the use of stub reinforcements that develop the required strength of the pole is permitted, provided the pole above the ground is in good condition and is of sufficient size to develop its required strength.

261. A. Poles and Towers—Continued.

5. TRANSVERSE-STRENGTH REQUIREMENTS FOR STRUCTURES WHERE SIDE GUYING IS REQUIRED, BUT CAN ONLY BE INSTALLED AT A DISTANCE.

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

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

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

(c) The entire section between the transversely strong structures shall comply with the highest grade of construction concerned in the given section, except as to the transverse strength of the intermediate poles or towers.

Grade C. The above provision is not applicable to grade C.

261. A. Poles and Towers—Continued.

6. LONGITUDINAL-STRENGTH REQUIREMENTS FOR SECTIONS OF HIGHER GRADE IN LINES OF A LOWER GRADE OF CONSTRUCTION.

(a) METHODS OF PROVIDING LONGITUDINAL STRENGTH.

Grade B. The longitudinal-strength requirements for sections of line of higher grade in lines of a lower grade (for assumed longitudinal loading, see rule 252, C, 1) are usually met by placing supporting structures of the required longitudinal strength at either end of the higher-grade section of the line.

Where this is impracticable, the supporting structures of the required longitudinal strength may be located one or more span lengths away from the section of higher grade, within 500 feet on either side and with not more than 800 feet between the longitudinally strong structures, provided such structures and the line between them meet the requirements as to transverse strength and stringing of conductors, of the highest grade occurring in the section, and provided that the line between the longitudinally strong structures is approximately straight or suitably guyed.

The requirements may also be met by distributing the head guys over two or more structures on either side of the crossing, such structures and the line between them complying with the requirements for the crossing as to transverse strength and as to conductors and their fastenings.

Where it is impracticable to provide the longitudinal strength, the longitudinal loads shall be reduced by increasing the conductor sags. This may require greater conductor separations. (See rule 235, A, 2, (a).)

Grade C. The above provision is not applicable to grade C.

261. A. Poles and Towers—Continued.

(b) Flexible Supports.

Grade B. When supports of the section of higher grade are capable of considerable deflection in the direction of the line, as with wood or concrete poles, or some types of metal poles and towers, it may be necessary to increase the normal clearances specified in section 23, or to provide head guys or special reinforcement to prevent such deflection.

So-called flexible steel towers or frames, if used at such locations, shall be adequately reinforced to meet the requirements of rule 261, A, 3 (b).

When the situation is one involving an isolated crossing of higher grade in a line of lower-grade construction, then the structure shall, when practicable, be head-guyed or otherwise reinforced to prevent reduction in the clearances required in section 23.

Grade C. The above provision is not applicable to grade C.

7. STRENGTH AT ANGLES IN A LINE.

At an angle in the line, the strength of a pole at the ground line, if not guyed, or at the point of guy attachment if guyed, shall be sufficient to withstand a combination of the transverse and longitudinal loadings specified in rule 252, B, 6. For grade B the transverse load shall be multiplied by 2.0 and for grade C by 1.5, before combining with the load arising from change in direction of conductors. The allowable percentage of ultimate stress at dead-ends given in rule 261, A, 4 (b) shall not be exceeded for the total load thus computed.

261. Grades B and C Construction—Continued.

B. Foundations.

1. USE OF FOUNDATIONS.

(a) WOOD AND REINFORCED-CONCRETE POLES. No special foundation construction is generally required.

(b) STEEL POLES OR TOWERS. Steel poles or towers set in earth shall be suitably protected against injurious corrosion at and below the ground line.

2. STRENGTH OF FOUNDATIONS.

(a) STEEL SUPPORTS. The foundations and footings shall be so designed and constructed as to withstand the stresses due to the loads assumed in rule 252. Steel parts shall withstand these loads with the overload capacity factors specified in table 16.

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

(b) WOOD AND CONCRETE POLES. Foundations and settings for unguyed poles shall be such as to withstand the loads assumed in rule 252 A, B, and C.

C. Guys.

1. GENERAL.

The general requirements for guys are covered under "Miscellaneous Requirements" (sec. 28).

2. FOR POLES IN INSECURE EARTH.

Where crossing poles are set in insecure earth the transverse strength requirements should, where practicable, be met by the use of side guys or braces.

261. C. Guys—Continued.

3. ON STEEL STRUCTURES.

The use of guys to obtain compliance with these requirements is regarded as generally undesirable. When guys are necessarily used, the steel supports or towers, unless capable of considerable deflection, shall be regarded as taking all of the load up to their allowable working load, and the guys shall have sufficient strength to take the remainder of the assumed maximum load. (See rule 261, A, 6, (b) for flexible supports.)

4. ON WOOD OR CONCRETE POLES.

When guys are used to meet the strength requirements for wood or concrete poles, they shall be considered as taking the entire load in the direction in which they act, the poles acting as struts only. Frequently the use of shorter spans or larger poles will permit the omission of guys at crossings.

5. STRENGTH OF GUYS.

(a) Guys, when required, shall be of such material and dimensions as will withstand the transverse loads assumed in rule 252, B, 1 to 5, inclusive, and the longitudinal load assumed in rule 252, C, without exceeding the following percentages of their ultimate strength:

	Percentages of ultimate strength	
	Grade B	Grade C
For transverse strength (when installed)	37. 50	50. 00
For longitudinal strength (at all times):		
In general	100. 00	No requirement.
At dead-ends	[1] 66. 67	[1] 87. 50

[1] If deflection of supporting structures is taken into account in the computations, 66⅔ percent shall be reduced to 60 percent and 87½ percent shall be reduced to 75 percent.

261. C. Guys—Continued.

(b) At an angle in the line, the strength of a transverse guy or guys shall be sufficient to withstand the combination of transverse and longitudinal loadings specified in rule 252, B, 6. The transverse load shall be multiplied by 1.78 for both grades B and C before combining with the load arising from the change in direction of conductors. The allowable percentage of ultimate strength at dead-ends given in (a) above shall not be exceeded for the total load thus computed.

D. Crossarms.

1. VERTICAL STRENGTH.

Crossarms shall, when installed, withstand the vertical loads specified in rule 252, A without the stress under these loads exceeding 50 percent of the assumed ultimate stress of the material.

Exception: For built up steel crossarms on steel structures, see table 16 for minimum overload capacity factors.

2. BRACING.

Crossarms shall be securely supported by bracing, if necessary, so as to support safely all other loads to which they may be subjected in use, including linemen working on them. Any crossarm or buckarm except the top one shall be capable of supporting a vertical load of 225 pounds at either extremity in addition to the weight of the conductors.

3. LONGITUDINAL STRENGTH.

(a) GENERAL. Crossarms shall withstand any unbalanced longitudinal loads to which they are exposed, with a limit of unbalanced tension where conductor pulls are normally balanced, of 700 pounds at the outer pin.

261. D. Crossarms—Continued.

(b) At Dead-ends and at Ends of Higher-Grade Construction in Line of Lower Grade.

Grade B. Wood crossarms shall be of sufficient strength to withstand at all times, without exceeding their ultimate stresses, an unbalanced pull equal to the tension in all supported conductors under the assumed conductor loading given in rule 251. Steel arms shall withstand this load with the overload capacity factor for longitudinal loads given in table 16.

Grade C. The above provisions do not apply to grade C.

(c) At Ends of Transversely Weak Sections.

Grade B. The crossarms connected to the structure at each end of the transversely weak section, such as described in rule 261, A, 5, shall be such as to withstand at all times without exceeding their ultimate stresses, under the conductor loading prescribed in rule 251, an unbalanced load equivalent to the combined pull in the direction of the transversely weak section of all the conductors supported.

Grade C. The above provision does not apply to grade C.

(d) Methods of Meeting Rules 261, D, 3, (b) and (c).

Grade B. Where conductor tensions are limited to a maximum of 2,000 pounds per conductor, double wood crossarms fitted with spacing bolts equipped with spacing nuts and washers, pipe spacers, or similar construction, or with spacing blocks or plates, will be considered as meeting the

261. D. Crossarms—Continued.

strength requirements in (b) and (c) preceding.

Grade C. The above provisions do not apply to grade C.

4. DIMENSIONS OF CROSSARMS OF SELECTED YELLOW PINE OR FIR.

The cross-sectional dimensions of selected yellow pine or fir crossarms shall be not less than the values of table 21.

TABLE 21.—*Crossarm cross sections*

Number of pins	Grade B	Grade C	
		Supply	Communication
	Inches	*Inches*	*Inches*
2 or 4	3 by 4	2¾ by 3¾	----------
6 or 8	3¼ by 4¼	3 by 4	----------
6	----------	----------	2¾ by 3¾
10	----------	----------	3 by 4

5. DOUBLE CROSSARMS OR BRACKETS.

Grade B. Where pin-type construction is used, two points of support shall be provided for each conductor by means of double crossarms or double brackets at each crossing structure, at ends of joint use or conflict sections, at dead-ends, and at corners where the angle of departure from a straight line exceeds 20 degrees.

Exception: Where communication cables or conductors cross below supply conductors and are attached to the same pole, the above does not apply unless another condition which requires double pins and fastenings for the supply conductors is involved.

Grade C. The above provision applies to grade *C* where supply conductors of more than 5,000

261. D. Crossarms—Continued.

volts between wires (or of more than 2,900 volts to ground in the case of grounded neutral circuits) cross over minor communication lines at locations such that the supply pole is more than 6 feet from the nearest communication conductor, unless other means of providing equivalent safety and strength are agreed to by the parties involved.

6. LOCATION.

In general, crossarms should be maintained at right angles to the axis of the pole and to the direction of the attached conductors. At crossings, crossarms should be attached to that face of the structure away from the crossing, unless special bracing or double crossarms are used.

E. Pins and Conductor Fastenings.

1. LONGITUDINAL STRENGTH

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

(b) AT DEAD-ENDS AND AT ENDS OF HIGHER-GRADE CONSTRUCTION IN LINE OF LOWER GRADE.

Grade B. Pins and ties or other conductor fastenings connected to the structure at each end of the higher-grade section shall be of sufficient strength to withstand at all times without exceeding their ultimate strength, an unbalanced pull due to the conductor loading specified in rule 251.

Grade C. The above provisions do not apply to grade C.

(c) AT ENDS OF TRANSVERSELY WEAK SECTIONS.

Grade B. Pins and ties or other conductor fastenings connected to the structure at

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261. E. Pins and Conductor Fastenings—Continued.

each end of the transversely weak section as described in rule 261, A, 5 shall be such as to withstand at all times without exceeding their ultimate strength under the conductor loading prescribed in rule 251, the unbalanced pull in the direction of the transversely weak section of the conductor supported.
Grade C. The above provisions do not apply to grade C.

(d) Method of Meeting Rules 261, E, 1, (b), and (c).

Grade B. Where conductor tensions are limited to 2,000 pounds and such conductors are supported on pin insulators, double pins, and ties or equivalent fastenings will be considered to meet the requirements of (b) and (c) preceding.
Grade C. The above provision does not apply to grade C.

2. SHARP EDGES ON FASTENINGS.

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

3. HEIGHT OF PIN.

The height of the pin and the conductor fastenings and the material and cross section of the pin should be chosen so as to afford the required strength.

Note: The method of attaching conductors by suitable ties to single pin-type insulators mounted on 1½ by 9 inch wood pins of locust or equivalent wood will usually provide strength up to 1,000 pounds conductor tension with the conductor 3.5 inches above the crossarm. Steel pins may afford greater strength, both for the pins and for the crossarms.

261. E. Pins and Conductor Fastenings—Continued.

4. DOUBLE PINS AND CONDUCTOR FASTENINGS.

Grade B. Where pin-type construction is used, two points of support shall be provided for each conductor by means of double pins and conductor fastenings at each crossing structure, at ends of joint use or conflict sections, at dead-ends, and at angles where the angle of departure from a straight line exceeds 20 degrees.

Exception: Where communication cables or conductors cross below supply conductors and are attached to the same pole, the above does not apply unless another condition which requires double pins and fastenings for the supply conductors is involved.

Grade C. The above provision applies to grade C where supply conductors of more than 5,000 volts between wires (or of more than 2,900 volts to ground in the case of grounded neutral circuits) cross over minor communication lines at locations such that the supply pole is more than 6 feet from the nearest communication conductor, unless other means of providing equivalent safety and strength are agreed to by the parties involved.

F. Open Supply Conductors.

1. MATERIAL.

Conductors shall be of material or combinations of materials which will not corrode excessively under the prevailing conditions.

Recommendation: It is recommended that hard-drawn or medium-hard-drawn copper wire (conforming to the specifications of the American Society for Testing Materials) be used instead of soft in new construction where bare wire or cable is used, especially for sizes smaller than No. 2.

261. F. Open Supply Conductors—Continued.

2. MINIMUM SIZES OF SUPPLY CONDUCTORS.

Supply conductors, both bare and covered, shall have an ultimate strength and an over-all diameter of metallic conductor not less than that of medium-hard-drawn copper of the gage size AWG shown in table 22, except that conductors made entirely of bare or galvanized iron or steel shall have an over-all diameter not less than Stl. WG of the gage sizes shown.

Exception 1: At railroad crossings, for stranded conductors, other than those in which a central core wire is entirely covered by the outside wires, any individual wire of such a stranded conductor containing steel shall be not less than 0.100 inch in diameter if copper-covered and not less than 0.115 inch in diameter if otherwise protected or if bare.

Exception 2: Supply service leads of 0 to 750 volts to ground may have the sizes set forth in rule 263, E.

Exception 3: Where the short-span method of construction is employed in accordance with rule 261, K, the conductor sizes and sags herein specified are not required.

TABLE 22.—*Minimum over-all conductor sizes*

Grade of construction	Gage size [1]
B	6
C	8

[1] For No. 6 and No. 8 medium-hard-drawn copper wire the nominal diameters are 0.1620 and 0.1285 inch, and the minimum values of breaking load are 1,010 and 643.9 pounds, respectively. For steel wire gage the nominal diameters are 0.192 inch for No. 6 and 0.162 inch for No. 8.

3. LIGHTNING PROTECTION WIRES.

Lightning-protection wires paralleling the line conductors shall be regarded in respect to size, material, and stringing requirements as supply conductors with which they are associated.

261. F. Open Supply Conductors—Continued.

4. SAGS AND TENSIONS.

Conductor sags shall be such that, under the assumed loading of rule 251 for the district concerned, the tension of the conductor shall be not more than 60 percent of its ultimate strength. Also the tension at 60° F, without external load, shall not exceed the following percentages of the conductor ultimate strength:

Initial unloaded tension------35 percent.
Final unloaded tension-------25 percent.

Exception: In the case of conductors having a cross section of a generally triangular shape, such as cables composed of three wires, the final unloaded tension at 60° F shall not exceed 30 percent of the ultimate strength of the conductor.

Note: The above limitations are based on the use of recognized methods for avoiding fatigue failures by minimizing chafing and stress concentration. If such practices are not followed, lower tensions should be employed.

5. SPLICES AND TAPS.

Grade B. Splices shall as far as practicable be avoided in the crossing and adjacent spans. If it is impracticable to avoid such splices, they shall be of such a type and so made as to have a strength substantially equal to that of the conductor in which they are placed.

Taps shall be avoided in the crossing span where practicable, but if required shall be of a type which will not impair the strength of the conductors to which they are attached.

Grade C. The above does not apply to grade C.

6. TROLLEY CONTACT CONDUCTORS.

In order to provide for wear, no trolley contact conductor shall be installed of less size than No. 0, if of copper, or No. 4, if of silicon bronze.

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261. Grades B and C Construction—Continued.

G. Supply Cables.

1. SPECIALLY INSTALLED SUPPLY CABLES.

Cables having effectively grounded continuous metal sheath or armor, where located on jointly used poles, or where located on other poles and having a grade of construction less than that required for open wire supply lines of the same voltage, shall meet the requirements of (a), (b), (c), and (d) below.

(a) MESSENGERS. Messengers shall be stranded and of corrosion-resistant material, and shall not be stressed beyond 60 percent of their ultimate strength under the loadings specified in rule 251.

(b) GROUNDING OF CABLE SHEATH AND MESSENGER. Each section of cable between splices shall be suitably and permanently bonded to the messenger wire at not less than two places. The messenger wire shall be grounded at the ends of the line and at intermediate points not exceeding 800 feet apart. (See section 9 for method.)

(c) CABLE SPLICES. Splices in the cable shall be made so that their insulation is not materially weaker than the remainder of the cable. The sheath or armor at the splice shall be made electrically continuous.

(d) CABLE INSULATION. The conductors of the cable shall be insulated so as to withstand a factory potential test of at least twice the operating voltage at operating frequency applied continuously for 5 minutes between conductors and between any conductor and the sheath or armor.

261. G. Supply Cables—Continued.

2. OTHER SUPPLY CABLES.

The following requirements apply to all supply cables not included in 1 above.

(a) MESSENGER. The messenger shall be of corrosion-resistant material, and shall not be stressed beyond 60 percent of its ultimate strength under the loadings specified in rule 251.

(b) CABLE. There are no strength requirements for cables supported by messengers.

H. Open-wire Communication Conductors.

Open-wire communication conductors in grade B or C construction shall have the sizes and sags given in rule 261, F, 2 and 4 for supply conductors of the same grade.

Exception: Where open-wire communication conductors in spans of 150 feet or less are above supply circuits of 5,000 volts or less between conductors, grade C sizes and sags may be replaced by grade D sizes and sags, except that where the supply conductors are trolley-contact conductors of 0 to 750 volts to ground, No. 12 wire may be used for spans of 0 to 100 feet, and No. 9 steel wire may be used for spans of 125 to 150 feet.

I. Communication Cables.

1. METAL-SHEATHED COMMUNICATION CABLES.

There are no strength requirements for such cables supported by messengers.

2. MESSENGER.

The messenger shall be of corrosion-resistant material, and shall not be stressed beyond 60 percent of its ultimate strength under the loadings specified in rule 251.

261. Grades B and C Construction—Continued.

J. Paired Communication Conductors.

1. PAIRED CONDUCTORS SUPPORTED ON MESSENGER.

(a) USE OF MESSENGER. A messenger of corrosion-resistant material may be used for supporting paired conductors in any location, but is only required for paired conductors crossing over trolley-contact conductors of more than 7,500 volts to ground.

(b) SAG OF MESSENGER. Messenger used for supporting paired conductors required to meet grade B construction because of crossing over trolley-contact conductors shall meet the sag requirements for grade D messengers.

(c) SIZE AND SAG OF CONDUCTORS. There are no requirements for paired conductors when supported on messenger.

2. PAIRED CONDUCTORS NOT SUPPORTED ON MESSENGER.

(a) ABOVE SUPPLY LINES.

Grade B. Sizes and sags shall be not less than those required by rule 261, F, 2 and 4 for supply conductors of similar grade.

Grade C. Sizes and sags shall be not less than the following:

Spans 0 to 100 feet. No sag requirements. Each conductor shall be of corrosion-resistant material, and shall have an ultimate strength of not less than 170 pounds.

Spans 100 to 150 feet. Sizes and sags shall be not less than required for grade D communication conductors.

Spans exceeding 150 feet. Sizes and sags shall be not less than required for grade C supply conductors. (See rule 261, F, 4.)

261. J. Paired Communication Conductors—Continued.

(b) Above Trolley-Contact Conductors.

Grade B. Sizes and sags shall be not less than the following:

Spans 0 to 100 feet. No size requirements. Sags shall be not less than for No. 8 AWG hard-drawn copper. (See rule 261, F, 4.)

Spans exceeding 100 feet. Each conductor shall be of corrosion-resistant material, and shall have an ultimate strength of not less than 170 pounds. Sags shall be not less than for No. 8 AWG hard-drawn copper. (See rule 261, F, 4.)

Grade C. Sizes and sags shall be as follows:

Spans 0 to 100 feet. No requirements.

Spans exceeding 100 feet. No sag requirements. Each conductor shall be of corrosion-resistant material, and shall have an ultimate strength of not less than 170 pounds.

K. Short-Span Crossing Construction.

Where supply lines cross over railways or communication lines by the short-span method, the requirements for grade B or C conductor sags and sizes are waived, in so far as such grades are required by the crossing, provided that an effectively grounded guard arm is installed at each cross-over support in such a manner as to prevent conductors which break in either adjoining span from swinging back into the conductors crossed over, or in the case of a railroad crossing into the space between the crossing supports.

Note: The short-span method of crossing requires the cross-over span to be of such a height that a conductor breaking in that span cannot come within 15 feet of the ground or rails at a railroad crossing or make contact with any wires crossed over at a wire crossing.

This character of construction is facilitated where the cross-over supports can be placed quite near together and in the case of wire crossings where the span crossed over is at a minimum elevation above ground.

261. Grades B and C Construction—Continued.

L. Cradles at Supply-Line Crossings.

Cradles should not be used.

Note: It is less expensive and better to build the supply line strong enough to withstand extreme conditions than to build a cradle of sufficient strength to catch and hold the supply line if it falls.

M. Protective Covering or Treatment for Metal Work.

All hardware, including bolts, washers, guys, anchor rods, and similar parts of material, subject to injurious corrosion under the prevailing conditions, shall be protected by galvanizing, painting, or other treatment which will effectively retard corrosion.

262. Grade D Construction.

A. Poles.

1. STRENGTH OF UNGUYED POLES.

Unguyed poles, except as provided in rule 262, A, 8, shall withstand the vertical and transverse loads specified in rule 252, A and B, and the longitudinal loads specified in rule 252, C, 4, without exceeding the following percentages of their ultimate stress:

	Percentages of ultimate stress
For transverse loads:	
When installed	25. 0
At replacement	37. 5
For longitudinal loads:	
When installed	75. 0
At replacement	100. 0

2. STRENGTH OF GUYED POLES.

Where poles are guyed, the poles shall be considered as acting as struts, resisting the vertical component of the tension in the guy, calculated as in rule 262, C, combined with the vertical load.

262. A. Poles—Continued.

3. STRENGTH REQUIREMENTS FOR POLES WHERE GUYING IS REQUIRED, BUT CAN ONLY BE INSTALLED AT A DISTANCE.

Where on account of physical conditions it is impracticable to guy or brace the crossing poles as specified in rule 262, C the requirements there given may be met by head-guying and side-guying the line as near as practicable to the crossing, but at a distance not exceeding 500 feet from the nearest crossing pole, provided that the line is approximately straight and that a stranded steel wire or other standard strand of strength equivalent to that of the head guy is run between the two guyed poles, being attached to the guyed poles at the point at which the head guys are attached, this wire being securely attached to every pole between the guyed poles.

4. POLE LOCATIONS AT CROSSINGS.

Where communication lines cross over railroads, the poles shall be located as follows:

(*a*) The poles supporting the crossing span and the adjacent spans should be located in a straight line, if practicable. Where the poles supporting the crossing span and the adjacent spans are not in line, guying shall be placed to take care of the unbalanced load.

(*b*) The crossing span shall, where practicable, not exceed 100 feet in the heavy loading district, 125 feet in the medium loading district, and 150 feet in the light loading district.

5. FREEDOM FROM DEFECTS.

Wood poles shall be of suitable and selected timber free from observable defects that would decrease their strength or durability.

262. A. Poles—Continued.

6. MINIMUM POLE SIZE.

Wood poles shall have a nominal top circumference of not less than 15 inches.

7. SPLICED AND STUB-REINFORCED POLES.

Spliced poles shall not be used at grade D crossings. At crossings over minor railroad tracks, the use of stub-reinforcements that develop the required strength of the pole is permitted, provided the pole above the ground line is in good condition and is of sufficient size to develop its required strength.

8. POLES LOCATED AT CROSSINGS OVER SPUR TRACKS.

Where a communication line paralleling a railroad track on the right-of-way of the railroad crosses a spur or stub track without any change in the general direction of line, the transverse strength requirements for grade D construction may be met without the use of side guys, provided the pole is not stressed beyond one-third of its ultimate stress. No requirements for longitudinal strength are made if the conductor tensions are balanced. Where conductor tensions are not balanced, due to a small angle in the line at one or both poles, or to dead-ending any of the wires, either guys or braces capable of withstanding such unbalanced tensions shall be installed.

B. Pole Settings.

Foundations and settings for unguyed poles shall be such as to withstand the loads assumed in rule 252, A, B, and C.

C. Guys.

1. GENERAL.

The general requirements for guys are covered under "Miscellaneous Requirements" (sec. 28).

262. C. Guys—Continued.

2. WHERE USED.

Side guys or braces shall be used on poles supporting the crossing span to withstand the loads put upon them in accordance with the conditions specified in rule 252, B.

Head guys shall be installed in accordance with table 23.

Exception 1: Side guys are not required where the crossing poles have the transverse strength specified in rule 262, A, 1 without the reduction for conductor shielding specified in rule 252, B, 1 and 2.

Exception 2: Head guys are not required where the crossing poles have the longitudinal strength specified in rule 262, A, 1, or where they carry a cable supported on 6,000-pound or stronger messenger.

Exception 3: Where a line crossing a railroad changes direction more than 10 degrees at either crossing support, the side guy within the angle may be omitted and the head guy, if required, shall be placed in the direction of the adjacent span unless the angle of turn is greater than 60 degrees.

Exception 4: Guying may be omitted where communication lines cross over spur or stub tracks as provided in rule 262, A, 8.

Exception 5: This rule does not apply to crossing poles under the special conditions set forth in rule 262, A, 3.

262. C. Guys—Continued.

TABLE 23.—*Strength (in pounds) of head guys required for loading districts indicated* [1]

[Combinations of standard-size guys may be used]

Number of wires	Ratio of guy lead to height not less than—				
	1¼	1	¾	⅔	½
HEAVY LOADING					
2	4, 000	4, 000	4, 000	4, 000	4, 000
6	4, 000	4, 000	4, 000	4, 000	6, 000
10	6, 000	6, 000	6, 000	10, 000	10, 000
20	10, 000	10, 000	12, 000	16, 000	16, 000
30	16, 000	16, 000	20, 000	20, 000	26, 000
40	20, 000	20, 000	26, 000	26, 000	32, 000
50	20, 000	20, 000	30, 000	32, 000	42, 000
60	26, 000	30, 000	36, 000	36, 000	48, 000
70	30, 000	30, 000	40, 000	48, 000	60, 000
80	36, 000	40, 000	48, 000	60, 000	70, 000
MEDIUM LOADING					
2	4, 000	4, 000	4, 000	4, 000	4, 000
6	4, 000	4, 000	4, 000	4, 000	4, 000
10	4, 000	4, 000	6, 000	6, 000	6, 000
20	6, 000	10, 000	10, 000	10, 000	12, 000
30	10, 000	10, 000	12, 000	16, 000	16, 000
40	12, 000	16, 000	16, 000	16, 000	20, 000
50	16, 000	16, 000	20, 000	20, 000	26, 000
60	20, 000	20, 000	26, 000	26, 000	30, 000
70	20, 000	20, 000	26, 000	30, 000	36, 000
80	26, 000	26, 000	30, 000	32, 000	40, 000
LIGHT LOADING					
2	4, 000	4, 000	4, 000	4, 000	4, 000
6	4, 000	4, 000	4, 000	4, 000	4, 000
10	4, 000	4, 000	4, 000	4, 000	4, 000
20	4, 000	6, 000	6, 000	6, 000	10, 000
30	6, 000	10, 000	10, 000	10, 000	12, 000
40	10, 000	10, 000	10, 000	12, 000	16, 000
50	10, 000	10, 000	16, 000	16, 000	20, 000
60	12, 000	16, 000	16, 000	16, 000	20, 000
70	16, 000	16, 000	20, 000	20, 000	26, 000
80	16, 000	20, 000	20, 000	26, 000	30, 000

[1] This table is based on ultimate or breaking strength of guys equal to seven-sixths of the nominal strengths shown in the table and a wire load of 50 percent No. 8 BWG iron and 50 percent No. 9AWG copper with an average pull of 408.75 pounds per wire.

No guy will be required for cable, since the messenger serves as a head guy.

262. C. Guys—Continued.

3. GUYS USED FOR TRANSVERSE STRENGTH.

Side guys used in straight sections of line shall be considered as taking the entire load in the direction in which they act, without exceeding 37.5 percent of their ultimate strength.

4. GUYS USED FOR LONGITUDINAL STRENGTH.

(a) DIRECTION OF HEAD GUYS. Where head guys are required, they shall be installed in the direction away from the crossing.

(b) SIZE AND NUMBER OF HEAD GUYS. Guys, if required for various open-wire loads, shall be in accordance with table 23.

5. MAINTENANCE.

Guys and anchors shall be maintained so that the guys carry the load.

D. Crossarms.

1. MATERIAL.

Wood crossarms supporting the crossing span shall be of yellow pine, fir, or other suitable timber.

2. MINIMUM SIZE.

(a) WOOD CROSSARMS. Wood crossarms shall have a cross section not less than the following:

Maximum number of wires to be carried	Nominal length		Nominal cross section (Inches)
	Feet	Inches	
2	1	4½	2$\frac{5}{16}$ by 3$\frac{5}{16}$
4	3	4½	2$\frac{5}{16}$ by 3$\frac{5}{16}$
6	6	0	2¾ by 3¾
10	8	6	2¾ by 3¾
10	10	0	3 by 4
12 [1]	10	0	3¼ by 4¼
16 [2]	10	0	3¼ by 4¼

[1] Where crossarms are bored for ½-inch steel pins, 3-inch by 4¼-inch crossarms may be used.

[2] Permitted in medium and light loading districts only.

262. D. Crossarms—Continued.

(b) Steel or Iron Crossarms. Galvanized or painted iron or steel crossarms of strength equal to wood crossarms may be used.

3. DOUBLE CROSSARMS.

Crossarms and insulators shall be double on the crossing poles. The crossarms shall be held together with properly fitted spacing blocks or bolts placed immediately adjoining the outside pins. Spacing blocks or spacing bolts are not required for two-pin crossarms.

E. Brackets and Racks.

Wood brackets may be used only if used in duplicate or otherwise designed so as to afford two points of support for each conductor. Single metal brackets, racks, drive hooks or other fixtures may be used if designed and attached in such manner as to withstand the full dead-end pull of the wires supported.

F. Pins.

1. MATERIAL.

Insulator pins shall be of steel, wrought iron, malleable cast iron, or locust or equivalent wood.

2. STRENGTH.

Insulator pins shall have sufficient strength to withstand the loads to which they may be subjected.

3. SIZE.

(a) Wood Pins. Wood pins shall be sound and straight-grained with a diameter of shank not less than 1¼ inches.

(b) Metal Pins. Steel or iron pins shall have diameter of shank not less than ½ inch.

G. Insulators.

Each insulator shall be of such pattern, design, and material that when mounted it will withstand without injury and without being pulled off the pin, the ultimate strength of the conductor attached to the insulator.

262. Grade D. Construction—Continued.

H. Attachment of Conductor to Insulator.

The conductors shall be securely tied to each supporting insulator.

I. Conductors.

1. MATERIAL.

Conductors shall be of material or combinations of materials which will not corrode excessively under the prevailing conditions.

2. SIZE.

Conductors of the crossing span, if of hard-drawn copper or galvanized steel, shall have sizes not less than specified in (a) and (b) below. Conductors of material other than the above shall be of such size and so strung as to have a mechanical strength not less than that of the sizes of copper conductors given in (a) and (b) below.

(a) SPANS NOT EXCEEDING 150 FEET. The sizes in table 24 apply for all loading districts.

TABLE 24.—*Minimum wire sizes*

[AWG for copper; Stl. WG for steel]

Conductor	Spans of 125 feet or less	Spans 125 to 150 feet
Copper, hard-drawn	10	9
Steel, galvanized:		
In general	10	8
In rural districts of arid regions	12	10

(b) SPANS EXCEEDING 150 FEET. If spans in excess of 150 feet are necessary, the size of conductors specified above or the sags of the conductors shall be correspondingly increased.

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262. I. Conductors—Continued.

3. PAIRED CONDUCTORS WITHOUT MESSENGERS.

Paired wires without a supporting messenger shall be eliminated as far as practicable and where used shall meet the following requirements:

(a) MATERIAL AND STRENGTH. Each conductor shall be of material or combinations of materials which will not corrode excessively under the prevailing conditions and shall have an ultimate strength of not less than 170 pounds.

(b) LIMITING SPAN LENGTHS. Paired wires shall in no case be used without a supporting messenger in spans longer than 100 feet in the heavy loading district, 125 feet in the medium loading district, and 150 feet in the light loading district.

4. SAGS.

Table 25 specifies the recommended sags for wires shown in table 24.

TABLE 25.—*Stringing sags*

HEAVY AND MEDIUM LOADING DISTRICTS

Length of span	100°F	80°F	60°F	40°F	20°F	0°F
Feet	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
70	5.7	4.4	3.4	2.7	2.2	1.8
75	6.4	5.1	4.0	3.1	2.5	2.1
80	7.4	5.8	4.5	3.5	2.9	2.4
85	8.4	6.6	5.1	4.0	3.2	2.7
90	9.4	7.3	5.7	4.5	3.6	3.0
95	10.0	8.2	6.3	5.0	4.0	3.4
100	11.6	9.0	7.0	5.5	4.5	3.7
110	14.0	11.0	8.5	6.7	5.4	4.5
120	16.6	13.0	10.1	7.9	6.4	5.4
130	19.5	15.3	11.8	9.3	7.6	6.3
140	22.6	17.7	13.7	10.8	8.8	7.3
150	26.0	20.3	15.8	12.4	10.1	8.4

262. I. Conductors—Continued.

TABLE 25.—*Stringing sags*—Continued

LIGHT LOADING DISTRICT

Length of span	110°F	100°F	80°F	60°F	40°F	20°F	10°F
Feet	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
80	5.5	5.0	4.2	3.4	2.8	2.4	2.2
85	6.2	5.7	4.7	3.9	3.2	2.7	2.5
90	7.0	6.4	5.3	4.3	3.6	3.0	2.8
95	7.8	7.1	5.8	4.8	4.0	3.4	3.1
100	8.6	7.9	6.5	5.3	4.4	3.7	3.5
110	10.4	9.5	7.8	6.5	5.4	4.5	4.2
120	12.4	11.3	9.3	7.7	6.4	5.4	5.0
130	14.6	13.3	11.0	9.0	7.5	6.3	5.9
140	16.9	15.4	12.7	10.5	8.7	7.3	6.8
150	19.4	17.7	14.6	12.0	10.0	8.4	7.8

5. SPLICES AND TAPS.

Splices shall as far as practicable be avoided in the crossing and adjacent spans. If it is impracticable to avoid such splices, they shall be of such a type and so made as to have a strength substantially equal to that of the conductor in which they are placed.

Taps shall be avoided in the crossing span where practicable, but if required shall be of a type which will not impair the strength of the conductors to which they are attached.

J. Messengers.

1. MINIMUM SIZE.

(*a*) SPANS NOT EXCEEDING 150 FEET. Table 26 gives the minimum sizes of galvanized steel-strand messenger to be used for supporting different sizes of cables:

TABLE 26.—*Minimum sizes of messenger*

Size of cable in weight per foot	Messenger (nominal breaking load)
	Pounds
Less than 2.25 pounds	6,000
2.25 to 5 pounds	10,000
Exceeding 5 and less than 8.5 pounds	16,000

262. J. Messengers—Continued.

(*b*) Spans Exceeding 150 Feet. For spans exceeding 150 feet or for heavier cables a proportionately larger messenger or other proportionately stronger means of support shall be used.

2. SAGS AND TENSIONS.

Multiple-conductor cables and their messengers shall be so suspended that when they are subjected to the loading prescribed in rule 251, the tension in the messenger will not exceed 60 percent of its ultimate strength.

K. Inspection.

See rule 213.

263. Grade N Construction.

A. Poles and Towers.

Poles used for lines for which neither grade B, C, or D is required shall be of such initial size and so guyed or braced, where necessary, as to withstand safely the loads to which they may be subjected, including linemen working on them. Such poles and stubs on State and Federal highways shall be located as far as practicable from the traveled portion of such highways. The number of crossings over such highways should be kept to a minimum. Such poles and stubs located within falling distance of the traveled portion of such highways, or so located that their failure would permit wires, cables, guys, or other equipment to fall into the traveled portion of the highway, or would reduce the clearances specified in table 1 over the traveled portion of such highways, shall be periodically inspected and maintained in safe condition.

B. Guys.

The general requirements for guys are covered under "Miscellaneous Requirements" (sec. 28).

263. Grade N Construction—Continued.

C. Crossarm Strength.

Crossarms shall be securely supported, by bracing if necessary, so as to support safely loads to which they may be subjected in use, including linemen working on them. Any crossarm, or buckarm, except the top one, shall be capable of supporting a vertical load of 225 pounds at either extremity, in addition to the weight of the conductors.

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

D. Supply-line Conductors.

1. MATERIAL.

All supply-line conductors shall be of material or combinations of materials which will not corrode excessively under the prevailing conditions.

2. SIZE.

Supply-line conductors shall be not smaller than the following:

TABLE 27.—*Grade N minimum sizes for supply-line conductors*

[AWG for copper and aluminum; Stl. WG for steel]

	Urban	Rural
Soft copper	6	8
Medium or hard-drawn copper	8	8
Steel	9	9
	Urban and rural	
	Spans 150 feet or less	Spans exceeding 150 feet
Stranded aluminum:		
Not reinforced	1	0
Steel-reinforced	6	4

263. D. Supply-line Conductors—Continued.

Recommendation: It is recommended that, except as modified in rule 261, F, 2, these minimum sizes for copper and steel not be used in spans longer than 150 feet for the heavy-loading district, and 175 feet for the medium- and light-loading districts.

E. Supply Services.

1. MATERIAL.

All supply service conductors shall be of material or combinations of materials which will not corrode excessively under the prevailing conditions.

2. SIZE OF OPEN-WIRE SERVICES.

(a) NOT OVER 750 VOLTS BETWEEN CONDUCTORS. Supply-service leads of not over 750 volts between conductors shall be not smaller than required by (1) or (2) below:

(1) SPANS NOT EXCEEDING 150 FEET. Sizes shall be not smaller than specified in table 28.

TABLE 28.—*Minimum sizes of service leads carrying 750 volts or less*

[All voltages are between conductors except trolley-contact conductors where voltages are to ground]

[AWG for copper; Stl. WG for steel]

Situation	Copper wire		Steel wire
	Soft-drawn	Medium or hard-drawn	
Alone	10	12	12
Concerned with communication conductors	10	12	12
Over supply conductors of—			
0 to 750 volts	10	12	12
750 to 8,700 volts [1]	8	10	12
Exceeding 8,700 volts [1]	6	8	9
Over trolley-contact conductors—			
0 to 750 volts ac or dc	8	10	12
Exceeding 750 volts ac or dc	6	8	9

[1] Installation of service leads of not more than 750 volts above supply lines of more than 750 volts should be avoided where practicable.

263. E. Supply Services—Continued.

(2) SPANS EXCEEDING 150 FEET. Sizes shall be not smaller than required for Grade C. (Rule 261, F, 2.)

(b) EXCEEDING 750 VOLTS BETWEEN CONDUCTORS. Sizes of supply-service leads of more than 750 volts between conductors shall be not less than required for supply-line conductors of the same voltage.

3. SAG, OPEN-WIRE SERVICES.

(a) NOT OVER 750 VOLTS BETWEEN CONDUCTORS. Supply service leads of not over 750 volts between conductors shall have sags not less than shown in table 29.

TABLE 29.—*Sags for open-wire services*

Span lengths	Sag
Feet	*Inches*
100 or less	12.
100 to 125	18.
125 to 150	27.
Exceeding 150	Grade C sags.

(*b*) EXCEEDING 750 VOLTS BETWEEN CONDUCTORS. Supply service leads of more than 750 volts between conductors shall comply as to sags with the requirements for supply line conductors of the same voltage.

4. CABLED SERVICES.

Supply service leads may be grouped together in a cable, provided the following requirements are met:

(*a*) SIZE. The size of each conductor shall be not less than required for leads of separate conductors (rule 263, E, 2).

(*b*) SAG. The sag of the cable should be not less than required for leads of separate conductors (rule 263, E, 3).

263. E. Supply Services—Continued.

(*c*) Insulation. The insulation should be sufficient to withstand twice the normal operating voltage.

F. Lightning-Protection Wires.

Lightning-protection wires paralleling the line conductors shall be regarded, in respect to size and material requirements, as supply conductors.

G. Trolley-Contact Conductors.

In order to provide for wear, no trolley-contact conductors shall be installed of less size than No. 0, if of copper, or No. 4, if of silicon bronze.

H. Cradles at Supply-Line Crossings.

Cradles should not be used.

Note: It is less expensive and better to build the supply line strong enough to withstand extreme conditions than to build a cradle of sufficient strength to catch and hold the supply line if it falls.

I. Communication Conductors.

There are no specific requirements for grade N communication line conductors or service drops.

SEC. 27. LINE INSULATORS

270. Application of Rule.

These requirements apply only to supply lines in situations where grade B construction is required. (See rule 242, E, for insulation requirements for neutral conductors.)

271. Material and Marking.

Insulators for operation on supply circuits at voltages of 2,300 and above shall be of porcelain, made by the wet process or one equally suitable as regards electrical and mechanical properties, or other material which will give equally good results in respect to mechanical and electrical performance and durability. They should be marked by the maker with his name, trade-mark, or identification number so applied as not to reduce the electrical or mechanical strength of the insulator.

272. Electrical Strength of Insulators in Strain Position.

Where insulators are used in a strain position they shall have not less electrical strength than the insulators generally used on the line when under the normal mechanical stresses imposed by the loadings specified in section 25.

273. Ratio of Flash-Over to Puncture Voltage.

Insulators shall be designed so that their dry flash-over voltage is not more than 75 percent of their puncture voltage at a frequency of 60 cycles per second.

274. Test Voltages.

Insulators when tested under the current specifications of the American Standards Association shall not flash over at values less than given in table 30.

Table 30.—*Test-voltage requirements*

[For application see rules 276 and 278]

Nominal voltage between conductors	Minimum test dry flash-over voltage of insulators	Nominal voltage between conductors	Minimum test dry flash-over voltage of insulators
750	5,000	46,000	125,000
2,400	20,000	69,000	175,000
7,200	40,000	115,000	315,000
13,200	55,000	138,000	390,000
23,000	75,000	161,000	445,000
34,500	100,000	230,000	640,000
(Interpolate for intermediate values.)			

275. Factory Tests.

Each insulator or insulating part thereof for use on circuits operating at voltages in excess of 15,000 volts shall be subjected to a routine dry flash-over test at the factory for a period of 3 minutes at a frequency of 60 cycles per second or to any other test sanctioned by good modern practice, such as high-frequency tests.

276. Selection of Insulators.

A. Insulators for Constant-Current Circuits.

Insulators for use on constant-current circuits shall be determined on the basis of the nominal full-load voltage of the circuit.

B. Insulators for Single-phase Circuits Directly Connected to Three-phase Circuits.

Insulators used on single-phase circuits directly connected to three-phase circuits (without intervening isolating transformers) shall have a flash-over voltage not less than that required for the insulators on the three-phase circuits.

C. Insulators for Nominal Voltages Between Conductors.

In selecting insulators of the test voltage to be used for any nominal voltage between conductors, consideration shall be given to the conditions under which the line will operate as follows:

1. Where the system is of moderate extent, in open country, subject to intermittent rains and moderate lightning, insulators having flash-over values not less than given in table 30 shall be used.
2. Where operating conditions are more severe than set forth in 1 above, due to extent of system, prevalence of exceptionally severe lightning, bad atmospheric conditions (caused by chemical fumes, smoke, cement dust, salt fog, or other foreign matter), or to a long, dry season with heavy dust accumulation followed by moisture, insulators having a higher flash-over than given in table 30 or other equally effective means of increasing insulation shall be used. The increase is to be determined by local conditions and experience.

277. Protection Against Arcing.

In installing the insulators and conductors, such precautions as are sanctioned by good modern practice shall be taken to prevent, as far as possible, any arc from forming or to prevent any arc which might be formed from injuring or burning any parts of the supporting structures, insulators or conductors which might render the conductors liable to fall.

278. Compliance With Rule 277 at Crossings.

Construction in accordance with any one of the methods (A to G) given below will be considered as a means of meeting the requirements of rule 277 above, provided that insulators having a flash-over not less than required by rule 276, C, 1 or C, 2 are used, and in no case having a lower flash-over than insulators generally used in adjacent sections of the line.

Exception: If the insulator hardware on the structure is grounded at crossings and is not grounded on the adjacent parts of the line, construction in accordance with A or B below should be followed, or other equally effective means employed.

The use of grounded construction at crossings only should in general be avoided.

A. The use of a protective device such as a gap, protector tube, lightning arrester, or the like, on or adjacent to the insulator, which is effective in suppressing the power arc or in holding it clear of the insulator, conductor, supporting structure, and hardware.

B. The use of protective gaps or other voltage-limiting devices on structures adjacent to crossing structures, if such devices limit the voltage to not more than 80 percent of the flash-over value of the insulators on the crossing structures.

C. The use of circuit protection by fast-clearing fuses or circuit-breakers. Fuses, or breakers in combination with their relays, shall be considered "fast-clearing" if they interrupt fault currents within one-fifth second (12 cycles at 60 cycles per second).

278. Compliance With Rule 277 at Crossings—Continued.

D. The use of one or more overhead ground wires installed at a higher level than the phase wires on not less than five consecutive spans, including two adjacent spans on each side of the crossing span, provided the ground wire is effectively grounded at structures adjacent to crossing structures.

Such overhead ground wires shall not be grounded at crossing structures unless such structures are inherently grounded or unless the ground wires are grounded at each of the two supporting structures on both sides of and adjacent to the crossing structures. In this latter case the down leads from the overhead ground wires shall be suitably offset from the crossing structures or otherwise arranged so as not to appreciably increase the probability of lightning flash-over from the overhead ground wire and its connections to the phase wires and other current-carrying parts.

E. The use of insulators with ungrounded pins or supporting insulator attachments carried on wood arms.

F. The use of insulators having a flash-over 25 percent greater than those employed on adjacent sections of the line, but not less than 25 percent greater than the values in table 30.

G. If the insulator supports on the crossing structure and on adjacent sections of the line are grounded, the use of insulator strings with higher flash-over voltage at crossing supports than on the adjacent sections, as follows:

(1) If the adjacent parts of the line have five or less units—one extra unit at the crossing.

(2) If the adjacent parts of the line have six or more units—two extra units at the crossing.

(3) Insulation equivalent to that provided by (1) or (2).

280. Supporting Structures for overhead lines.

A. **Poles and Towers.**

1. RUBBISH.

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

2. GUARDING POLES.

(*a*) Protection Against Mechanical Injury. Where poles and towers are exposed to abrasion by traffic or to other damage which would materially affect their strength, they shall be protected by guards.

(b) Protection Against Climbing. On closely latticed poles or towers carrying supply conductors exceeding 300 volts to ground, either guards or warning signs shall be used, except as follows:

Exception 1: Where the right-of-way is completely fenced.

Exception 2: Where the right-of-way is not completely fenced, provided the poles or towers are not adjacent to roads, regularly traveled thoroughfares, or places where people frequently gather, such as schools or public playgrounds.

3. WARNING SIGNS.

(a) On Poles or Towers. For warning signs on poles or towers, see rule 280, A, 2, (b).

(b) On Bridge Fixtures. Structures attached to bridges for the purpose of supporting conductors shall be plainly marked with the name, initials, or trade-mark of the utility responsible for the attachment and, in addition, where the voltage exceeds 750 volts to ground, by the following sign or its equivalent:

"Danger—Do Not Touch."

280. A. Poles and Towers—Continued.

4. GROUNDING METAL POLES.

Metal poles not guarded or isolated shall always be specially grounded where in contact with metal-sheathed cable or the metal cases of equipment operating at voltages exceeding 750 volts to ground.

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

5. POLE STEPS.

(a) METAL STEPS. Steps closer than 6½ feet from the ground or other readily accessible place shall not be placed on poles.

(b) WOOD BLOCKS. One wood block (or on private right-of-way more than one) may be placed on poles carrying communication cables or conductors below supply conductors, but the lowest block is not to be less than 3½ feet from the ground or other readily accessible place. On poles carrying only communication conductors, additional wood blocks may be used.

6. IDENTIFICATION OF POLES.

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

280. A. Poles and Towers—Continued.

7. OBSTRUCTIONS.

All poles should be kept free from posters, bills, tacks, nails, growing vines, and other unnecessary obstructions, such as through bolts not properly trimmed.

B. Crossarms.

1. LOCATION.

In general, crossarms should be maintained at right angles to the axis of the pole and to the direction of the attached conductors, and at crossings should be attached to that face of the structure away from the crossing, unless special bracing or double crossarms are used.

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

2. BRACING.

Crossarms shall be securely supported, by bracing if necessary, so as to support safely loads to which they may be subjected, including linemen working on them. Any crossarm or buckarm, except the top one, shall be capable of supporting a vertical load of 225 pounds at either extremity in addition to the weight of the conductors.

C. Unusual Conductor Supports.

Where conductors are attached to structures other than those used solely or principally for supporting the lines, all rules shall be complied with as far as they apply and such additional precautions as may be deemed necessary by the administrative authority shall be taken to avoid injury to such structures or to the person using them. The supporting of conductors on trees and roofs should be avoided where practicable.

281. Tree Trimming.

A. General.

Where trees exist near supply-line conductors, they shall be trimmed, if practicable, so that neither the movement of the trees nor the swinging or increased sagging of conductors in wind or ice storms or at high temperatures will bring about contact between the conductors and the trees.

Exception: For the lower-voltage conductors, where trimming is difficult, the conductor may be protected against abrasion and against grounding through the tree by interposing between it and the tree a sufficiently nonabsorptive and substantial insulating material or device.

B. At Wire Crossings and Railroad Crossings.

The crossing span and the next adjoining spans shall be kept free, as far as practicable, from overhanging or decayed trees which might fall into the line.

282. Guying.

A. Where Used.

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

Guys shall be used also, where necessary, wherever conductor tensions are not balanced, as at corners, angles, dead-ends, and changes of grade of construction.

Note: This is to prevent unduc increase of sags in adjacent spans as well as to provide sufficient strength for those supports on which the loads are considerably unbalanced.

B. Strength.

The strength of the guy shall meet the requirements of section 26 for the grade of construction that applies.

When guys are used with wood or other poles or

282. B. Strength—Continued.

towers capable of considerable deflection before failure, the guys shall be able to support the entire load in the direction in which they act, the pole acting simply as a strut.

C. Point of Attachment.

The guy should be attached to the structure as near as practicable to the center of the conductor load to be sustained, but for voltages exceeding 8,700 volts between conductors, the insulation afforded by wood crossarms and poles should not be reduced any more than is necessary.

D. Guy Fastenings.

Guys should be stranded and where attached to anchor rods should be protected by suitable guy thimbles or their equivalent. Cedar and other softwood poles around which any guy having a strength of 10,000 pounds or more is wrapped should be protected by the use of suitable guy shims and, where there is a tendency for the guy to slip off the shim, guy hooks or other suitable means of preventing this action should be used. Shims are not necessary in the case of supplementary guys, such as storm guys.

E. Guy Guards.

The ground end of all guys attached to ground anchors exposed to traffic shall be provided with a substantial and conspicuous wood or metal guard not less than 8 feet long.

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

F. Insulating Guys from Metal Poles.

Where anchors would otherwise be subject to electrolysis, guys attached to metal poles or structures and not containing guy insulators should be insulated from the metal pole or structure by suitable blocking.

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282. Guying—Continued.

G. Anchor Rods.

Anchor rods shall be installed so as to be in line with the pull of the attached guy when under load, except in rock or concrete. The anchor rod shall have an ultimate strength in the eye and shank equal to that required of the guy.

H. Grounding.

The anchored end of guys attached to wood poles carrying circuits of more than 15,000 volts shall be effectively grounded (see section 9 for method) wherever this part of the guy has a clearance of less than 8 feet to ground.

Exception 1: This does not apply to guys in rural districts.

Exception 2: This does not apply if the guy contains an insulator which will meet the requirements of rule 283, A, 2 for the highest voltage liable to be impressed on it.

283. INSULATORS IN GUYS ATTACHED TO POLES AND TOWERS.

A. Properties of Guy Insulators.

1. MATERIAL.

(a) GRADE B. Guy insulators shall be made by the wet-porcelain process or a process equally suitable as regards electrical and mechanical properties.

(b) GRADES C, D, AND N. No requirements are made for material.

2. ELECTRICAL STRENGTH.

Guy insulators shall have a dry flash-over voltage at least double the normal line voltage and a wet flash-over voltage at least as high as the normal line voltage between conductors.

3. MECHANICAL STRENGTH.

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

283. Insulators in Guys Attached to Poles and Towers—Continued.

B. Use of Guy Insulators.

1. ONE INSULATOR.

An insulator shall be located in each guy which is attached to a pole or structure carrying any supply conductors of more than 300 volts to ground and not more than 15,000 volts between conductors, or in any guy which is exposed to such voltages. This guy insulator shall be located at least 8 feet above the ground.

Exception 1: A guy insulator is not required where the guy is grounded under the conditions set forth in 4 following.

Exception 2: A guy insulator is not required if the guy is attached to a pole on private right-of-way carrying no supply circuits whose voltage exceeds 550 volts or whose transmitted power exceeds 3,200 watts.

Exception 3: A guy insulator is not required if all supply conductors are in a cable having a grounded metal sheath or supported by a grounded messenger.

2. TWO INSULATORS.

Where a guy attached to any pole carrying communication or supply conductors or both, is carried over or under any overhead supply conductor of more than 300 volts to ground and where hazard would otherwise exist, two or more guy insulators shall be placed so as to include the exposed section of the guy between them as far as possible. Neither insulator shall be within 8 feet of the ground.

Exception: These insulators are not required where the guy is grounded under the conditions set forth in 4 following.

283. B. Use of Guy Insulators—Continued.

3. RELATIVE LOCATION OF INSULATORS IN GUYS LOCATED ONE ABOVE THE OTHER.

Where guys in which it is necessary to install insulators are so arranged that one crosses or is above another, insulators shall be so placed that in case any guy sags down upon another the insulators will not become ineffective.

4. GROUNDING OF GUYS.

Insulators are not required in guys under the following conditions:

(a) Where the guy is electrically connected to grounded steel structures or to a ground connection on wood poles.

(b) Where the guys are uniformly effectively grounded throughout any system of overhead lines.

(c) Where the guys are connected to a line conductor which has at least four ground connections in each mile of line in addition to the ground connections at individual services.

284. SPAN-WIRE INSULATORS.

A. Mechanical Strength.

Span-wire insulators shall have a mechanical strength at least equal to that required of the span wire in which they are installed.

B. Use of Span-Wire Insulators.

All span wires, including bracket span wires, shall have a suitable strain insulator (in addition to an insulated hanger if used) inserted between each point of support of the span wire and the lamp or trolley-contact conductor supported, except that single insulation, as provided by an insulated hanger, may be permitted when the span wire or bracket is supported on wood poles supporting only trolley, railway feeder, or communication conductors used in the operation of the railway con-

284. B. Use of Span-Wire Insulators—Continued.

cerned. In case insulated hangers are not used, the strain insulator shall be located so that in the event of a broken span wire the energized part of the span wire cannot be reached from the ground.

Exception: This rule does not apply to insulated feeder taps used as span wires.

285. Overhead Conductors.

A. Identification.

All conductors of electric-supply and communication lines should be arranged to occupy definite positions throughout, as far as practicable, or shall be constructed, located, marked, numbered, or attached to distinctive insulators or crossarms, so as to facilitate identification by employees authorized to work thereon. This does not prohibit systematic transposition of conductors.

B. Branch Connections.

1. ACCESSIBILITY.

Connections of branches to supply circuits, service loops, and equipment in overhead construction shall be readily accessible to authorized employees. When possible, connections shall be made at poles or other structures.

2. CLEARANCE.

Branch connections shall be supported and placed so that swinging or sagging cannot bring them in contact with other conductors or interfere with the safe use of pole steps, or reduce the climbing or lateral working space.

C. Common Neutral.

Primary and secondary circuits may utilize a single conductor as a common neutral if such conductor has at least four ground connections in each mile of line. Ground connections at individual services are to be counted only if made to underground water piping systems.

286. Equipment on Poles.

A. Identification.

All equipment of electric-supply and communication lines should be arranged to occupy definite positions throughout, as far as practicable, or shall be constructed, located, marked, or numbered so as to facilitate identification by employees authorized to work thereon.

B. Location.

Transformers, regulators, lightning arresters, and switches, when located below conductors or other attachments, shall be mounted outside of the climbing space.

C. Guarding.

Current-carrying parts of switches, automatic circuit-breakers, and lightning arresters shall be suitably inclosed or guarded if all the following conditions apply:

1. If of more than 300 volts to ground, and,
2. If located on the climbing side of the pole less than 20 inches from the pole center, and,
3. If located below the top crossarm.

D. Hand Clearance.

All current-carrying parts of switches, fuses, lightning arresters, also transformer connections and other connections which may require operation or adjustment while alive and are exposed at such times, shall be arranged so that in their adjustment while alive the hand need not be brought nearer to any other current-carrying part at a different voltage than the clearances from pole surfaces required in table 9, rule 235, A, 3, (a), for conductors of corresponding voltages. (See also rule 422, A, B, and C, part 4 of this code, for clearances from live parts.)

286. Equipment on Poles—Continued.

E. Street-Lighting Equipment.

1. CLEARANCES FROM POLE SURFACE.

All exposed metal parts of lamps and their supports (unless effectively insulated from the current-carrying parts) shall be maintained at the following distances from the surface of wood poles:

	Inches
In general	20
If located on the side of the pole opposite the designated climbing side	5

Exception: This does not apply where lamps are located at pole tops.

2. CLEARANCES ABOVE GROUND.

Street lamps shall be mounted at not less than the following heights above ground:

	Feet
Over walkways	10
Over roadways:	
Connected to circuits of 150 volts or less	14
Connected to circuits of more than 150 volts	15

3. HORIZONTAL CLEARANCE.

Arc and incandescent lamps in series circuits should have at least 3 feet horizontal clearance from windows, porches, and other spaces accessible to the general public.

4. MATERIAL OF SUSPENSION.

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

286. E. Street-Lighting Equipment—Continued.

5. INSULATORS IN SUSPENSION ROPES.

Effective insulators, as specified in rule 283, A, should be inserted at least 8 feet from the ground in metallic suspension ropes or chains supporting lighting units of series circuits.

6. ARC-LAMP DISCONNECTORS.

A suitable device shall be provided by which each arc-lighting unit on series circuits of more than 300 volts to ground may be safely and entirely disconnected from the circuit before the lamp is handled, unless the lamps are always worked on from suitable insulating stools, platforms, or tower wagons, or handled with suitable insulating tools, and treated as under full voltage of the circuit concerned.

7. GROUNDING LAMP POSTS.

Metal lamp posts shall be effectively grounded.

F. Transformers.

Transformers mounted on arms or poles on public thoroughfares shall be at a height above ground not less than 10 feet where over walkways and not less than 15 feet where over roadways.

Exception: Where it is the established practice to mount transformers at lesser distances above ground, such practice may be continued if the reduced mounting heights are carefully maintained.

287. Protection for Exposed Overhead Communication Lines.

A. Open Wire.

Communication lines for public use and fire-alarm lines shall be treated as follows, if at any point they are exposed to supply (including trolley) lines of more than 400 volts to ground:

1. At stations for public use they shall be protected by one of the methods specified in part 3, section 39 of this code.

287. A. Open Wire—Continued.

2. Elsewhere they shall be isolated by elevation or otherwise guarded so as to be inaccessible to the public.

B. Metal-Sheathed Cable.

Metal-sheathed cables and messengers shall be isolated or grounded in conformity with the general requirements of section 21.

288. Circuits of One Class Used Exclusively in the Operation of Circuits of Another Class.

A. Overhead Communication Circuits Used Exclusively in the Operation of Supply Circuits.

1. CHOICE OF METHOD.

Communication circuits used exclusively in the operation of supply lines may be run either as ordinary communication circuits or as supply circuits under the conditions specified in 3 and 4 of this rule, respectively. After selection of the type of communication-circuit construction and protection for any section which is isolated, or is separated by transformers, such construction and protection shall be consistently adhered to throughout the extent of such isolated section of the communication system.

2. GUARDING.

Communication circuits used in the operation of supply lines shall be isolated by elevation or otherwise guarded at all points so as to be inaccessible to the public.

3. WHERE ORDINARY COMMUNICATION-LINE CONSTRUCTION MAY BE USED.

Communication circuits used in the operation of supply lines may be run as ordinary communication conductors under the following conditions:

(a) Where such circuits are below supply conductors in the operation of which they are used (including high-voltage trolley feeders)

288. A. Overhead Communication Circuits Used Exclusively in the Operation of Supply Circuits—Continued.

at crossings, conflicts, or on commonly used poles, provided:

(1) Such communication circuits occupy a position below all other conductors or equipment at crossings, conflicts, or on commonly used poles.

(2) Such communication circuits and their connected equipment are adequately guarded and are accessible only to authorized persons.

(3) The precautions in part 3, section 39, and part 4, section 44 of this code, have been taken.

(b) Where such circuits are below supply conductors in the operation of which they are used and are above other supply or communication conductors at wire crossings, conflicts, or on the same poles, provided the communication circuits are protected by fuseless lightning arresters, drainage coils, or other suitable devices to prevent the communication circuit voltage from normally exceeding 400 volts to ground.

Note: The grades of construction for communication conductors with inverted levels apply.

4. WHERE SUPPLY-LINE CONSTRUCTION MUST BE USED.

Communication circuits used in the operation of supply lines shall comply with all requirements for the supply lines with which they are used, where they do not comply with the provisos of 3 (a) or (b) above.

Exception 1: If the voltage of the supply conductors concerned exceeds 8,700 volts between conductors, the communication conductors, need only meet the requirements for supply

288. A. Overhead Communication Circuits Used Exclusively in the Operation of Supply Circuits—Continued.

conductors of 5,000 to 8,700 volts between conductors.

Exception 2: Where the supply conductors are required to meet grade C, the size of the communication conductors may be the same as for grade D (see rule 262, I, 2) for spans up to 150 feet.

B. Supply Circuits Used Exclusively in the Operation of Communication Circuits. (See also sec. 29.)

Circuits used for supplying power solely to apparatus forming part of a communication system may be run either in open wire or in aerial or underground cable as follows:

1. Where run in open wire, such circuits shall have the grades of construction, clearances, insulation, etc., prescribed elsewhere in part 2 for supply or communication circuits of the voltage concerned.
2. Where run in aerial or underground cable and the following requirements are met, the grades of construction, clearances, separations, locations, etc., prescribed elsewhere in part 2 for communication cables shall apply:

   (a) Such cables are covered with effectively grounded continuous metal sheaths or are carried in metal cable rings on effectively grounded messengers.

   (b) All circuits in such cables are owned or operated by one party and are maintained only by qualified employees.

   (c) Supply circuits included in such cables are terminated at points accessible only to qualified employees.

   (d) Communication circuits brought out of such a cable, if they do not terminate in a repeater station or terminal office, shall be so protected or arranged that in the event of a

288. B. Supply Circuits Used Exclusively in the Operation of Communication Circuits—Continued.

failure within the cable, the voltage on these communication circuits will not exceed 400 volts to ground.

(e) Terminal apparatus for the power supply shall be arranged so that live parts are inaccessible when such supply circuits are energized.

Exception: The provisions of B, 1 and 2 above, do not apply to supply circuits of 550 volts or less and which carry power not in excess of 3,200 watts, covered in rule 220, B, 3.

289. Overhead Electric Railway Construction.

A. Trolley-Contact Conductor Supports.

All overhead trolley-contact conductors shall be supported and arranged so that the breaking of a single contact conductor fastening will not allow the trolley conductor, live span wire, or current-carrying connection to come within 10 feet (measured vertically) from the ground, or from any platform accessible to the general public.

Span-wire insulation for trolley-contact conductors shall comply with rule 284.

B. High-Voltage Contact Conductors.

Every trolley-contact conductor of more than 750 volts in urban districts where not on fenced right-of-way shall be suspended so as to minimize the liability of a break and, as far as practicable, so that if broken at a single point, it can not fall within 12 feet (measured vertically) from the ground or any platform accessible to the general public.

C. Third Rails.

Third rails shall be protected where not on fenced rights-of-way by adequate guards composed of wood or other suitable material.

289. Overhead Electric Railway Construction—Continued.

D. Prevention of Loss of Contact at Railroad Crossings.

Trolley-contact conductors shall be arranged as set forth in either 1 or 2 following, at grade crossings with interurban or other heavy-duty or high-speed railroad systems:

1. The trolley-contact conductor shall be provided with live trolley guards of suitable construction, or,

2. The trolley-contact conductor shall be as far as practicable at the same height above its own track throughout the crossing span and the next adjoining spans. Where a uniform height above rail is not adhered to, the change shall be made in a very gradual manner. Where the crossing span exceeds 100 feet, catenary construction shall be used.

Exception: This rule does not apply where the system is protected by interlocking derails or by gates.

E. Guards Under Bridges.

1. WHERE GUARDING IS REQUIRED.

Guarding is required where the trolley-contact conductor is so located that a trolley pole leaving the conductor can make simultaneous contact between it and the bridge structure.

2. NATURE OF GUARDING.

Guarding shall consist of a substantial inverted trough of nonconducting material located above the contact conductor, or other suitable means of preventing contact between the trolley pole and the bridge structure.

(See also rule 288, B, 2.)

290. LOCATION.

A. General Location.

Underground systems of electric conductors should be located so as to be subject to the least practicable disturbance. Railway tracks and underground structures, including catch basins, gas pipes, etc., should be avoided where practicable.

B. Ducts.

The ducts between adjacent manholes or other outlets should be laid as straight and direct as practicable.

C. Manholes.

Manhole openings, where practicable, shall be located so as to provide safe and convenient access. At crossings under railroads, the manholes, pull boxes, and terminals should, where practicable, be located away from the roadbed.

291. CONSTRUCTION OF DUCT AND CABLE SYSTEMS.

A. Material, Size, and Finish of Ducts.

Ducts shall be of such material, size, mechanical strength, and finish as to facilitate the installation and maintenance of conductors or cables. Ducts shall be freed from burrs before laying and shall have clear bores.

B. Grading of Ducts.

Where it is necessary to drain ducts the grade of the ducts shall be such as to permit proper and adequate drainage.

C. Settling.

Ducts should be suitably reinforced or be laid on suitable foundations of sufficient mechanical strength where necessary to protect them from settling.

291. Construction of Duct and Cable Systems—Continued.

D. Clearances.

1. GENERAL.

The clearance between duct or cable systems and other underground structures paralleling them, shall be as great as practicable. The distance between the top covering of the system and the pavement surface, or other surface under which the system is constructed, shall be sufficient to protect the system from injury by traffic.

2. BELOW BASE OF RAIL.

The top of all duct and cable system structures, except as hereafter specified, shall generally be located at a depth of not less than 30 inches, in the case of street railways, and not less than 42 inches, in the case of steam and electric railroads, below the base of rail. Where unusual conditions exist or where proposed construction would interfere with existing construction, a greater depth than specified above may be required.

Exception 1: Where this is impracticable, or for other reasons, this clearance may be reduced by agreement between the parties concerned. In no case, however, shall the top of the conduit protection extend higher than the bottom of the ballast section which is subject to working or cleaning.

Exception 2: Where physical and chemical conditions will permit, a conduit consisting of not more than two iron pipes, not exceeding 4 inches in diameter, or two creosoted wood ducts not exceeding 6 inches square, or one or more cables of a type designed for burying directly in the earth used for communication lines, or for service supply circuits not exceeding 750 volts, may be laid in the ground beneath railroad tracks without any form of

291. D. Clearances—Continued.

protection at a minimum depth of 18 inches below the base of the rail unless the worked ballast section of the roadbed exceeds 18 inches, in which case the conduit shall be laid below the ballast section.

3. IRON PIPE CONDUIT.

Where iron pipe is used as a conduit for underground cables or conductors, it shall not be laid in contact with water, gas, or steam metallic-pipe systems. Where the clearance is less than two inches, the metal conduit shall be adequately separated from other metallic-pipe systems by a barrier of suitable materials, or they shall be electrically bonded together at the point of least separation.

E. Separations Between Supply and Communication Duct Systems.

1. GENERAL.

Duct systems, including laterals, to be occupied by communication conductors for public use should be separated, where practicable, from duct systems, including laterals, for supply conductors by not less than 3 inches of concrete, 4 inches of brick masonry, or 12 inches of well-tamped earth.

Exception 1: Extensions may, however, be made to existing interconnected or jointly owned and jointly occupied duct systems used in common by municipalities, communication companies, or supply companies with less effective separations than above specified.

Exception 2: Cables containing circuits of 550 volts or less between conductors and having a total transmitted power of not in excess of 3,200 watts, used exclusively in connection with the operation of a railway signal or supply system, may be carried in the same

291. E. Separations Between Supply and Communication Duct Systems—Continued.

duct system with communication cables, if such construction is agreed to by all parties concerned, and where the communication cables are exclusively used for the operation of the railway signal or supply system, they may be carried in the same duct.

2. ENTERING MANHOLES.

Where communication and supply conductors or cables occupy ducts terminating in the same manhole, the two classes of ducts should be separated as widely as practicable and where practicable should enter the manhole from opposite sides.

Note: This requirement is made so that cables can be racked along side walls with a minimum of crosses between the two classes of conductors.

F. Duct Entrances Into Manholes.

Iron-pipe conduit terminating in manholes, handholes, or other permanent openings of underground systems, shall be provided with an effective shield, bushing or other smooth outlet.

Exception: This does not apply to communication conductors, to supply conductors of less than 300 volts between conductors, or to armored cables of any voltage.

G. Sealing Laterals.

Lateral ducts for service connections to buildings, through which gas or water may enter buildings or other duct systems, should be effectively plugged or cemented by the use of asphaltum, pitch, or other suitable means.

H. Duct Arrangement for Dissipation of Heat.

Duct systems intended to carry supply cables of large current capacity should be arranged, where practicable, so that ducts carrying such cables will not dissipate their heat solely through other ducts.

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292. Construction of Manholes.

A. **Minimum Strength.**

The design and construction of manholes and handholes shall provide sufficient strength to sustain, with a suitable margin of safety, the loads which may reasonably be imposed on them.

B. **Dimensions.**

Manholes should meet the following requirements where practicable:

1. WIDTH.

The least horizontal inside dimension should be not less than 3 feet 6 inches.

2. WORKING SPACE.

A clear working space should be provided. The horizontal dimension should be not less than 3 feet. The vertical dimension should be not less than 6 feet except in manholes where the opening is within 1 foot on each side of the full size of the manhole.

Exception: The dimensions specified in 1 and 2 above are not necessary in service boxes, handholes, or in manholes serving a small number of ducts, or in manholes used exclusively for communication-system equipment and cables.

C. **Drainage.**

Where drainage is into sewers, suitable traps shall be provided to prevent entrance of sewer gas into manholes.

D. **Ventilation.**

Adequate ventilation to open air shall be provided for manholes from which any openings exist into subways entered by the public. Where such manholes house transformers, sectionalizing switches, or regulators, etc., the ventilator ducts shall be cleaned at necessary intervals.

Exception: Subways under water or in other locations where it is impracticable to comply.

292. Construction of Manholes—Continued.

E. Manhole Openings.

Round openings to any manhole should be not less than 24 inches in diameter. Rectangular openings should have dimensions not less than 24 by 20 inches.

Exception: The dimensions specified above are not necessary in service boxes and handholes or in manholes serving a small number of ducts.

F. Manhole Covers.

Manholes and handholes, while not being worked in, shall be securely closed by covers of sufficient strength to sustain such loads as may reasonably be imposed upon them.

G. Supports for Cables.

Cables should be adequately supported at each manhole.

H. Manhole Location.

Manhole openings shall, where practicable, be located so that barriers or other suitable guards can be placed to protect the opening effectively when uncovered.

293. Location of Cables.

A. Accessibility.

Cables in manholes shall be reasonably accessible to workmen and clear working space shall be maintained at all times.

B. Cables Carrying Large Currents.

Cables intended to carry large currents should be located, where practicable, in outside ducts so that they will not necessarily dissipate heat solely through adjacent ducts.

C. Separation Between Conductors.

1. cables of different voltages.

Cables shall be arranged and supported in ducts and manholes so that those operating at higher

293. C. Separation Between Conductors—Continued.

voltages will be separated as far as practicable from those operating at lower voltages.

2. CABLES OF DIFFERENT SYSTEMS.

Cables belonging to different systems, particularly supply-distribution and communication systems, shall not be installed in the same duct.

Exception: This does not apply to the installation of railway-signal supply and communication cables in the same duct, as permitted by exception 2 in rule 291, E, 1.

3. CABLES OF SUPPLY AND COMMUNICATION SYSTEMS.

(a) GENERAL. Supply cables and communication cables for public use should, in general, be maintained in separate duct systems, and particularly in separate manholes.

Exception 1: Cable extensions may be made to existing interconnected or jointly owned and jointly occupied duct systems used in common by municipalities, communication companies, or supply companies.

Exception 2: This does not apply where railway-signal supply and communication cables are carried in the same duct system as permitted in exception 2, rule 291, E, 1.

(b) IN THE SAME MANHOLE. Supply cables and communication cables for public use occupying the same manhole should, where practicable, be maintained at opposite sides of the manhole.

Where supply and communication cables must cross, a separation of at least 1 foot shall, where practicable, be maintained.

294. Protection and Separation of Conductors Buried in Earth.

A. Separation.

The separation between buried communication and buried supply conductors or cables shall consist of not less than 12 inches of well tamped earth, 4 inches of brick, or 3 inches of concrete.

Exception: This separation and protection is not required where supply circuits having a potential of 550 volts or less between conductors and having a total transmitted power of not in excess of 3,200 watts are laid adjacent to communication cables, if all cables are used exclusively for the operation of a railway-signal or supply system, and are maintained by the same company.

B. Protection at Crossings of Cables.

At all crossings where buried supply conductors or cables are above communication conductors or cables, the supply conductors or cables shall be protected from digging operations by concrete or creosoted wood plank or equivalent mechanical protective covering extending at least 2 feet in each direction from the point of crossing.

Exception: This separation and protection is not required where supply circuits having a potential of 550 volts or less between conductors and having a total transmitted power of not in excess of 3,200 watts are laid adjacent to communication cables, if all cables are used exclusively for the operation of a railway-signal or supply system, and are maintained by the same company.

C. Protection of Cables Installed Parallel.

Where buried communication and buried supply conductors or cables are installed in the same trench generally parallel to each other, the buried supply conductors or cables shall be covered with

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294. C. Protection of Cables Installed Parallel—Continued.

concrete or creosoted wood plank or equivalent mechanical protection, except that this covering may be omitted in the following cases:

1. Where the voltage of the supply conductors does not exceed 300 volts to ground.
2. Where the supply conductors or cables are encased in a continuous metallic sheath effectively grounded.
3. Where the supply conductors or cables are installed more than 2 feet horizontally from communication conductors.

Exception: This separation and protection is not required where supply circuits having a potential of 550 volts or less between conductors and having a total transmitted power of not in excess of 3,200 watts are laid adjacent to communication cables, if all cables are used exclusively for the operation of a railway-signal or supply system, and are maintained by the same company.

295. PROTECTION OF CONDUCTORS IN DUCT SYSTEMS AND MANHOLES.

A. Protection Against Arcing.

A suitable fire-resistant covering should be placed on the following cables to prevent injury from arcing:

1. Closely grouped lead-sheathed supply cables containing circuits of more than 8,700 volts, or of large current capacity operating at more than 750 volts ac or 300 volts dc.
2. Communication cables and supply cables of large current capacity, if occupying the same side of the manhole, or if they cross each other.

B. Bonding.

Exposed metallic cable sheaths shall be bonded at suitable intervals with a conductor of suitable size, electrolysis conditions permitting. Supply cable sheaths need not be bonded to communication cable sheaths.

296. Guarding of Live Parts in Manholes.

A. Conductor Joints or Terminals.

Joints or terminals of conductors or cables of supply systems shall be arranged so that there are no bare ungrounded current-carrying metal parts exposed to accidental contact within manholes or handholes.

B. Apparatus.

Live parts of protective, control or other apparatus installed and maintained in manholes should be enclosed in suitable grounded cases or in cases having no exposed metallic parts.

297. Construction at Risers from Underground.

A. Separation Between Risers of Communication and Supply Systems.

The placing of risers for communication systems and risers for supply systems on the same pole should be avoided where practicable. If it is necessary to use the same pole for the risers of both systems, they shall be placed on opposite semicircumferences of the pole where practicable. Where located on streets or highways, risers should, where practicable, be placed on poles so as to be in the safest available location from the point of view of traffic damage.

B. Mechanical Protection of Conductors.

All supply conductors or cables from underground systems which connect to overhead systems shall be protected by a covering which gives suitable mechanical protection up to a point 8 feet above the ground.

Exception: Armored cables or cables installed in a grounded metal conduit.

C. Grounding of Riser Pipes.

Exposed metal riser pipes containing supply conductors shall be grounded unless such conductors are covered with a grounded metal sheath or are themselves grounded.

297. Construction at Risers from Underground—Continued.

D. Conductor Terminal Construction.

The terminals of underground cables operating at more than 750 volts to ground and connecting to overhead open-wire systems shall meet the following requirements:

1. PROTECTION AGAINST MOISTURE.

Protection shall be provided so that moisture will not enter the cable.

2. INSULATION OF CONDUCTORS.

Conductors shall be properly insulated from the grounded metal sheath. In addition, the conductors of multiple-conductor cable shall be properly separated and insulated from each other.

Note: These requirements may be fulfilled by the use of potheads or other equivalent devices, such as oil switches, if incidentally they accomplish the same purpose.

E. Clearance Above Ground for Open Supply Wiring.

For supply wires connecting to underground systems see rule 232, C.

298. IDENTIFICATION OF CONDUCTORS.

Cables shall be permanently identified by tags or otherwise at each manhole or other permanent opening of the underground system. Where the duct formation on opposite sides of the manhole is the same, the cables where practicable should be installed in corresponding ducts.

Exception: This requirement does not apply where the position of a cable, in conjunction with diagrams supplied to workmen, gives sufficient identification, or where the manhole is occupied solely by the communication cables of one utility, or of two utility companies agreeing thereto.

299. Identification of Apparatus Connected in Multiple.

Where transformers, regulators, or other similar apparatus not located in the same manhole operate in multiple, special tags, diagrams, or other suitable means shall be used to indicate that fact.

Exception: This requirement does not apply where disconnecting devices are provided to permit cutting such equipment completely off the system.

DISCUSSION OF SECTION 9.—RULES COVERING METHODS OF PROTECTIVE GROUNDING OF OVERHEAD AND UNDERGROUND LINES AND RELATED EQUIPMENT

CONTENTS

Object of Protective Grounds.

The object of protective grounds on electric circuits or equipment, as required by the rules of this code, is to keep some point in the electric circuit or equipment at, or as near as practicable to, the potential of the earth in the vicinity, in order to prevent the passage of dangerous amounts of current through the bodies of persons in case of accidental contact with the live conductors or conducting material. For discussion of methods of grounding, see discussion of rules 94 and 95.

The ideal condition would be to have a grounding electrode with a resistance to ground so small that the voltage to ground would be held to a small value under any condition. In many situations, however, this is not practicable, due to either high soil resistivity or the fact that the power circuit involved is of very low impedance. However, in such cases a high degree of protection is obtained if the grounding electrode has a low enough resistance to ground to insure enough current to promptly operate protective devices and thus remove the source of hazardous potential. For ground resistance, see discussion of rule 96.

90. Scope of the Rules.

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

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

91. Application of the Rules.

It is not expected that a set of rules or methods of procedure can be devised which will cover every individual case; hence, the application of the rules is left in special cases to the judgment of the administrative authority. In general, however, the rules should be adhered to wherever possible, because they represent the best that experience and experiment afford at the present time, and no departure should be made without mature consideration.

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

92. Point of Attachment of Grounding Conductor.

A. Direct-Current Distribution Systems.

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

B. Alternating-Current Distribution Systems.

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

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

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

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

If the secondary circuit loses its ground connection by the blowing of a fuse while the primary winding remains connected to the line a hazardous condition is created. To insure permanent continuity of the ground connection, ground connections and fuses should be so placed in relation to each other that the secondary winding is always connected to earth.

C. Current in Grounding Conductor.

Where multiple grounding is used, there will in general be some circulating current between the different ground connections. The advantage in permanency and reliability which results from the use of a number of grounds on a given circuit feeding a considerable area will generally warrant the use of multiple grounds on alternating-current secondaries, notwithstanding the possible existence of slight interchange of alternating current over these connections. However, a value of interchange current, which would not be harmful with alternating current, might be sufficient to cause damage if it were direct current. Such direct currents may flow over multiple grounding connections on a-c systems where such connections are in close proximity to electric railway returns. The objectionable d-c current can generally be eliminated by following one of the procedures recommended in the rules by either omitting or changing ground connections.

D. Equipment and Wire Raceways.

It is not intended that each length of conduit and each piece of equipment be separately grounded by independent grounding wires. Where a metal conduit or raceway system is employed it is sufficient to bond properly the different sections together either by separate bonds or through the junction boxes by scraping off paint and screwing the bushings and locknuts tight. Galvanized conduit and fittings may provide proper electrical continuity between the separate sections, and tests have not shown enameled conduit deficient in this respect.

E. Service Conduit.

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

93. Grounding Conductor.

A. Material and Continuity.

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

B. Size and Capacity.

The minimum allowable size of grounding conductors is determined principally by mechanical considerations, for they are more or less liable to mechanical injury and must therefore be strong enough to resist any strain to which they are likely to be subjected. The general practice in electrical construction has been to place the minimum size at No. 8 copper, for service or system grounding.

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

C. Mechanical Protection and Guarding Against Contact.

Where there is only a single grounding connection on a circuit, the path of the grounding conductor should be as far as possible out of reach of persons, and as much care should be taken to prevent contact of persons with it as would ordinarily be taken with a low-voltage circuit conductor. Where there are two or more grounding connections to a circuit, there is less likelihood of having a substantial potential on a grounding conductor.

94. Ground Connections.

A. Piping Systems.

On account of the great extent of water-piping systems, they constitute, in general, the best means of grounding electrical circuits and equipment. The resistance of water-pipe grounds ordinarily is less than 0.25 ohm. Water pipes appear at numerous points in a building and are interconnected or in contact with steam pipes, gas pipes, etc., so that they offer many chances for persons to come into contact with them. If a separate grounding electrode were employed for the electrical system instead of the water pipes, the voltage between such electrical system and the extensive piping system might be much larger and, therefore, the safety would be reduced. The very presence of these piping

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systems on the premises increases the importance of using them as grounding electrodes.

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

B. Alternate Methods.

Where extensive public piping systems are not available, the grounding connection should be made in a manner to secure the most effective ground. Frequently, there are buried structures such as local piping systems, building frames, well casings, and the like which would be more effective than separately driven or buried artificial grounds. In some situations, two or more of such structures can be bonded together. This will not only provide a lower-resistance ground, but will also lessen the chance of difference of potential within the premises.

C. Artificial Grounds.

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

D. Grounds to Railway Returns.

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

95. METHOD.

A. Piping.

Grounding connections for circuits should preferably be made immediately at the point where the water-service pipe enters the building, or, on a cold-water pipe of sufficient current-carrying capacity, as near as practicable to that point, in order to avoid a possible rise of potential on the building piping system in cases where disconnections are made for piping repairs. Grounding connections for equipment, raceways, and the like, do not present the same problem, since the loss of such a ground connection will ordinarily not cause a rise of potential in the disconnected piping system because the equipment frame or raceway is normally insulated from the enclosed energized conductors. In this case, there can be a rise of potential only where a leakage exists between the enclosure and the energized conductors at the time a disconnection is made in the piping system ahead of the point of ground connection.

Wherever practicable, the points at which grounding connections are made should be accessible to permit inspection after installation. Such accessibility permits ready detection of corroded or deteriorated connections and of whether the grounding connection may have been left disconnected following repairs to the piping system. Where fixtures are grounded to gas pipes, the gas pipe must be well bonded to the water-pipe system of the building.

The best place to connect to water piping is on the street side of water meters, but not infrequently cases arise where the meter is not within the building, so that connection must be made on the building side. It is then necessary to shunt the water meter to avoid breaking the ground connection in the event of removal of the meter.

B. Ground Clamps.

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

C. Contact Surfaces.

In every case where electrical continuity is desired for the purpose of grounding or bonding, the surfaces of the metals where they come in contact with each other should be carefully cleaned of enamel, paint, rust, or other nonconducting material. This aids in securing low resistance of the ground connection.

D. Electrodes for Artificial Grounds.

Artificial grounds may be made by means of driven rods, pipes, buried plates or buried strips of metal. The first two are most generally used. With regard to driven rods and pipes, it has been found that the size should be such that they can be satisfactorily driven to a depth of about eight feet. A layer of dry soil on the surface, of course, necessitates greater length of pipe, but after 8 feet of conducting soil has been penetrated, increased length does not give proportionate decrease of resistance. It is more economical to use several grounds in parallel, because if they are separated an adequate distance, the total resistance varies approximately inversely as the number.

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

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

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

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

96. GROUND RESISTANCE.

A. Limits.

The desirability of low resistance in ground connections is readily apparent. The lower the resistance of the ground, the less will be the potential difference between the grounded conductor and the earth. In any case, the resistance should be sufficiently low so that the faulted circuit is promptly de-energized. Where secondary-distribution circuits are provided with a ground of 25 ohms resistance or less, the current in case of a fault involving the primary-distribution circuit will, in general, be sufficient to de-energize the primary circuit at the transformer or elsewhere.

B. Checking.

The ammeter-voltmeter method of checking the resistance of ground connections is reliable and satisfactory but requires some source of power. Portable instruments especially designed for measuring the resistance of ground connections are now commercially available.

97. SEPARATE GROUNDING CONDUCTORS AND GROUNDS.

A. Grounding Conductors.

Where the failure of a single grounding conductor might produce undesirable potentials on the equipment or other apparatus, it is advisable to use separate grounding conductors. Connection of the separate conductors to the same ground electrode does not involve such potentials, since the separate grounding conductors cannot be in electrical connection with each other without being also connected to ground. Where multiple grounds are used, danger from the failure of individual grounding conductors is eliminated. The tendency today is to use a common grounding conductor of substantial cross section and multiple grounds rather than running separate ground wires to a single electrode. In case there is more than one service from the transformers, such multiple grounds are easily obtained.

DISCUSSION OF PART 2—SAFETY RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATION LINES

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FIGURES

DISCUSSION OF PART 2—SAFETY RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATION LINES

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

200. Scope of Rules.

A. Extent of Application.

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

B. Not Complete Specifications.

Practice and experience have determined reasonable limits for elevation of lines and equipment and for the strength of construction necessary. The rules do not provide such detailed requirements as are needed for construction specifications but are intended to include the more important requirements from the standpoint of safety to the public and to workmen, grading clearances by the degree of hazard involved, and grading strength requirements necessary to maintain the required clearances both by the degree of hazard and by the mechanical loads to which it is assumed the lines may be subjected.

C. Conformity with Good Practice.

The required construction is intended to be in accord with good practice and, indeed, to set a standard of good practice in many respects. Safety is promoted by uniformity in practice, which tends to avoid confusion and misunderstanding both in construction and operation.

201. Application of the Rules and Exemptions.

A. Intent, Modification.

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

B. Realization of Intent.

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

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

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

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

C. Waiver for Temporary Installations.

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

D. Waiver in Emergencies.

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

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

202. Minimum Requirements.

The rules are intended to be reasonable and adequate from the standpoint of safety, and it was with these thoughts in mind that the code rules were developed. In many particulars they do not require as substantial or expensive construction as many companies have found it expedient or desirable to provide for service or other reasons. As ex-

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perience justifies it, the requirements are expected to be modified in subsequent editions of the code.

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

210. Design and Construction.

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

211. Installation and Maintenance.

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

It is not sufficient to provide against possible hazards in new construction. Deterioration in materials of construction makes it essential that a check be kept on conditions and that adequate safety be preserved by inspection and maintenance. Certain of the rules specify quantitatively the amount of deterioration permissible before replacement, but, in general, this must depend upon the good judgment of those in charge. This subject is further considered in rule 213.

212. Accessibility.

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

213. Inspection and Tests of Lines and Equipment.

A. When in Service.

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

B. When Out of Service.

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

214. Isolation and Guarding.

A. Current-Carrying Parts.

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

215. Grounding of Circuits and Equipment.

A. Methods.

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

B. Parts to be Grounded.

The purpose of this rule is to protect persons coming into contact with metal conduit, cable sheaths, metal frames, cases, etc., from receiving a dangerous or fatal shock, as has often happened when such metallic bodies were ungrounded and in contact with supply circuits. This is one of the most important safeguards in handling supply equipment. If such equipment is out of reach from the ground, or if approached only by qualified workmen, grounding is not required.

216. Arrangement of Switches.

B. Indicating Open or Closed Position.

Inaccessible switches and switches that do not show at a glance whether they are open or closed tend to increase mistakes in operation and to multiply accidents. This is especially the case in emergencies when quick action is necessary and time cannot be taken for consideration of unusual connections or arrangement of switches.

C. Locking.

If practicable, means should be provided to lock or otherwise secure pole-top switches in either the open or closed position. Locking is especially important where men are working on a line which is made dead by a switch, the control mechanism of which is readily accessible to unauthorized persons.

D. Uniform Position.

Uniformity of position and of method of operation within a system makes it easier to avoid mistakes and so promotes rapid and safe operation.

SEC. 22. RELATIONS BETWEEN VARIOUS CLASSES OF LINES

220. Relative Levels.

A. Standardization of Levels.

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

B. Relative Levels—Supply and Communication Conductors.

1. PREFERRED LEVELS.

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

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

2. MINOR EXTENSIONS.

It would involve undue expense to specify the immediate standardization of all present construction in conformity with these rules. This would work a severe hardship on utilities in localities where it has been the practice to place the communication wires above the supply wires. A gradual change to the preferred type of construction is recommended. Small extensions of the present arrangement of levels may be made provided the construction conforms to the grade required for such arrangements.

3. SPECIAL CONSTRUCTION FOR SUPPLY CIRCUITS, ETC.

For many years it has been the practice of certain railroads to run circuits which supply power for operating signal circuits upon the lowest crossarm of the telegraph line. In view of this established practice, a special rule has been written which recognizes and permits the continuance of such an arrangement but only after cooperative consideration with the owners of other circuits which may be involved on the same line. Definite restrictions and limitations are applied to this practice. These limitations do not apply to circuits used for signaling purposes or train control, which meet the definition of communication circuits (sec. 1, definition 45) as these are not restricted as to common occupancy of crossarms with other communication circuits.

C. Relative Levels—Supply Lines of Different Voltage Classifications (as classified in table 11).

2. ON POLES USED ONLY BY SUPPLY CONDUCTORS.

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

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

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

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

221. Avoidance of Conflict.

Parallel lines offer three possibilities—overbuilding, conflict, and complete separation.

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

A distinction is made between a structure conflict and conductor conflict. These terms are separately defined in section 1. It is evident from these definitions that some conductors of a line may be in conflict while other conductors of the same line are not in conflict, and in such cases the grade of construction incidental to such conflict applies only to the former. A structure conflict may or may not be accompanied by conductor conflict, but in most cases it will be. It is desirable to avoid both types of conflict and such avoidance as referred to in this rule applies to both forms.

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

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

Where it is impracticable to secure separation beyond conflicting distance between the communication and supply lines, a choice must be made between a joint line and separate pole lines, one of which conflicts with the other. Both of these types of construction are covered by the rules.

There are cases where one method is to be preferred to the other. Conflicting lines which are not overbuilt naturally offer less opportunity for accidental contact between the conductors of the supply and communication lines, since the likelihood of a broken supply wire falling on a communication conductor is greatly reduced. The possibility of broken poles bringing the two classes of conductors into contact is also perhaps more remote with this method of construction. Such a conflicting line offers a less degree of hazard than a colinear line and also is preferable to joint use of poles, when considering supply lines which may impress upon the communication circuits a voltage against which the communication protective apparatus cannot function reliably. On the other hand, from the safety standpoint, a joint line is always preferable to overbuilding. Another benefit to be derived from the joint use of poles is the reduction in the number of supporting structures on the streets within municipalities.

Inasmuch as the available routes for the distribution networks of communication and supply services must frequently coincide, and as the users of both services are, to a large extent, common, the lines of both classes of service will, in general, occupy the same streets or alleys. As the voltage which such distribution supply circuits may impress upon communication circuits is generally within the limits of reliability of communication protective apparatus, a joint line of poles may be a suitable solution. Even when higher distribution voltages are involved, a joint line is usually regarded as safer than separate lines which must have numerous crossings under or over each other, including service drops to customers' premises, especially when the alternative is either a conflicting line or separate lines on opposite sides of a street, which under the definition are not in conflict, but yet involve the possibility of mechanical interference.

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

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

SEC. 23. CLEARANCES

230. General.

A. Application.

The clearances, climbing spaces, and separations specified are intended, under usual conditions of operation and without failure of conductors or structures, to prevent contact by persons with circuits or equipment and to prevent these facilities from coming in contact with other facilities.

B. Constant-Current Circuits.

Where a person may come into contact with a constant-current circuit, the hazard, assuming the circuit to be intact, depends mainly on the full-load voltage of the circuit. However, in the event of a contact of a constant-current circuit with other facilities, there may be an additional hazard occasioned by the value of current or the open-circuit voltage. So long as no open circuit occurs in the constant-current circuit however, the voltage of interest during a contact with other facilities would generally be the full-load voltage of the constant-current circuit.

C. Metal-Sheathed Supply Cables.

Where a supply cable is covered with a continuous grounded metal sheath or armor, or if not so covered is supported in metal rings contacting an effectively grounded messenger, high voltage cannot be carried on the external surface of the cable, because it is essentially at ground potential. It can, therefore, be regarded as a low-voltage conductor insofar as clearances are concerned. Where, however, cables are not effectively grounded, the external surface of a cable might have impressed upon it the full potential of the enclosed conductors. Consequently, such cables must then be classified the same as "open-supply conductors of the same voltage."

D. Neutral Conductors.

Where the neutral conductor of a multigrounded supply circuit of not in excess of 15,000 volts is effectively grounded throughout its length, there is little likelihood of its carrying potentials as high as 750 volts. Accordingly, neutral conductors of such multigrounded systems have been classified in the clearance section of the code, the same as a 0- to 750-volt open-supply conductor. Conversely, if the supply-circuit neutral conductor is not effectively grounded throughout its length, it may carry the phase-to-neutral potential, and is classified the same as the phase conductors with which it is associated. The above voltage limit of 15,000-volt multigrounded systems was determined upon because it represented the maximum line potential usually employed for such systems and with which there was sufficient experience to justify the reduced voltage limit for the neutral conductor.

231. Horizontal Clearances of Supporting Structures From Other Objects.

A. From Fire Hydrants.

A minimum clearance between line structures (including guys) and hydrants is required to make the latter readily accessible when needed.

B. From Street Corners.

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

232. Vertical Clearance of Wires Above Ground or Rails.

A. Basic Clearances.

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

In consideration, therefore, of accidents due to insufficient clearance or to high loads on vehicles, and in consideration of general practice and the advantage of a more nearly uniform practice, the clearances of table 1 have been established.

It is necessary that some uniform basis be established as the determining condition of the wire in the crossing span from which the required clearance shall be measured. Otherwise there would be confusion as to whether the minimum clearance applies with the wire in its initial unloaded, or in its final unloaded, condition at 60° F, no wind. As the prescribed clearances were determined on the basis of conductor sag increases from the final unloaded to the full load condition, it is obvious that, if the clearance were measured from the wire in its initial unloaded condition, there might subsequently develop an unsafe clearance reduction. It is the usual practice of supply utilities to design their lines on the final unloaded condition of the conductors, the conductors being strung to initial tension and then allowed to stretch to the predetermined final unloaded tension, or the wires prestressed and then slacked off to this latter tension. Consequently, the final unloaded condition of the wire was used as the basis for determining clearances, except in those cases where companies maintain their wires approximately at initial sags by the pulling out of slack. Communication companies which use close spacing of wires often follow this practice of pulling slack, in order to prevent swinging contacts that might result if sags increased appreciably.

Railway freight cars will usually not much exceed a height of 15 feet. In most communities cars of greater height are already eliminated by low highway bridges, which are often much lower than the wire clearances specified.

The basic clearances of 27, 28, and 30 feet are required for open conductors in crossings over railways where men are permitted on tops of freight cars, the clearance depending on the voltage of the line. For guys and for cables carried on messengers, 25 feet is considered an adequate clearance, since this clearance will not be reduced appreciably by temperature changes or ice loading.

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

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

The movement of such devices as hay stackers, well rigs, and derricks along highways must always be considered as extraordinary traffic and subject to the necessity of observing special precaution against contacts with overhead constructions of all kinds. Otherwise, such vehicles may endanger the community by injuring overhead structures. It is frequently practicable to reduce the height of such vehicles but this is often neglected, and the low wire elevation is sometimes blamed for avoidable accidents arising out of culpable negligence of the operators of the vehicles.

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

Supply-service leads, when of less than 150 volts to ground, may have a clearance of only 10 feet at the entrance of the service to the building. This exception is made, as it is often impracticable to give a greater clearance, and the voltage of the circuit does not offer any considerable hazard.

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

B. Increased Clearances.

Increased clearances are required for three different conditions, namely, spans exceeding specified limits, voltages exceeding 50,000, and certain types of supports involving suspension insulators. The rule states that these increases are cumulative where more than one applies. (For further discussion of increased clearances at railroad crossings, see discussion of rule 233,B.)

233. Wire-Crossing Clearances.

A. Basic Clearances.

The lines of voltage demarcation in table 3, as regards clearances, are expressed in terms of voltage between wires.

For example, the same clearance would be required for a 7,200-volt single-phase, Δ- or Y-connected system, irrespective of the voltage to ground of any one of these systems. A specific exception to this is provided in footnote 10 of table 3, allowing the same clearance for a multigrounded supply circuit operating at 8,700 to 15,000 volts between wires, but not in excess of 8,700 volts to ground, as for a supply circuit not exceeding 8,700 volts between wires (5,000 volts to neutral or ground). This was done in order not to change a practice that has developed in recent years, due to dual interpretations of the previous code requirements, which practice has not been found to increase hazards unduly so long as the communication-line span crossed over is relatively short. Where, however, this span is long and the communication-conductor sags are large, the crossing supply wire might be at a level below that up to which the communication conductors might whip, in the event of a sudden release of load thereon, or because of "dancing." To obviate this, the provision was inserted that, at 60° F, no wind, the supply conductor at the upper level must not sag below the line of sight between the points of support of the communication conductors in the crossing span, above which level the communication conductors will rarely pass even with large dancing amplitudes.

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. In the case of messenger wires supporting communication cables it is necessary that safe separation be provided from supply conductors, so that workmen out on the cable messenger are assured free access to all parts of the span.

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

With regard to footnote 7 to table 3, where the crossing or colinear wire is within 6 feet of, but not attached to, a support of the wires crossing beneath, the upper wires offer a hazard to linemen who might be working on the pole of the lower line at a time when the upper wires are sagged excessively under load. To alleviate this danger, added clearance between the facilities must be provided.

B. Increased Clearances.

Extensive use during the past several years of conductors of new types and combinations of materials, as well as relatively small conductors in long spans, necessitated development of a method for determining minimum allowable clearances above ground or rails and at wire crossings that differs materially from the one in previous editions of the code insofar as increased clearances for longer spans are

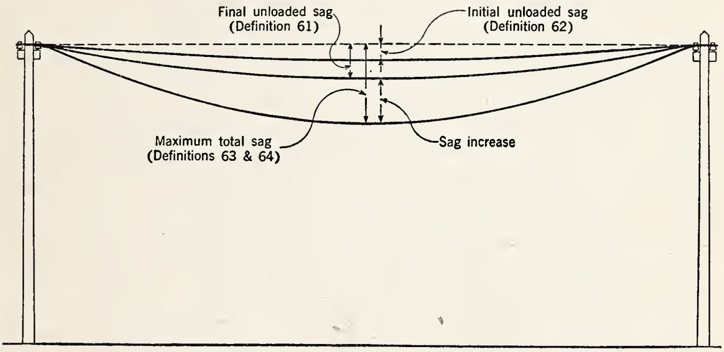

FIGURE 1.—*Sags.*

concerned. The basis of this new method is outlined in the following paragraphs.

Figure 1 shows the various sags that are of interest in considering clearances. All of these are defined in section 1, except sag increase, which is taken to be the arithmetic difference between final unloaded sag at 60° F, and total sag, or 120° F sag, whichever is the greater. The sag increase of particular interest is the "maximum sag increase" (msi) which is defined in rule 233,B,1(a).

It is known, of course, that conductors have greater sags when loaded with ice, or when subjected to high temperatures, than they have under normal conditions, and the amount of this increase in sag is a controlling factor in providing safe clearances. On the basis of data obtained from the manufacturers, curves were plotted of the sag increase with span length for all of the commonly used conductors in each of the three loading districts. Figure 2 shows one of those curves, and its shape is typical of conductors strung so as not to exceed definite percentages of their ultimate strengths. It will be noted that the sag increase at first becomes greater as the length of span becomes greater, but eventually a maximum point is reached beyond which the sag increase is less than this maximum. The maximum-sag-increase values have been determined for most of the more commonly used conductors and are given

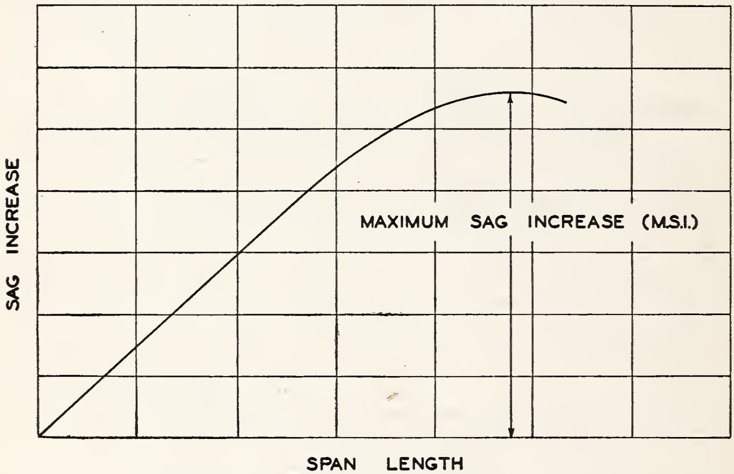

FIGURE 2.—*Typical sag-increase curve.*

in table D13,[1] Appendix 2A. Unless otherwise indicated, they are based on the assumption that the conductors are strung with the minimum sags, and therefore the maximum tensions, permitted by rule 261,F,4. If conductors are strung with less than these maximum tensions, it may be desirable to compute the corresponding sag increases and thus determine the maximum value. However, the values in this table may be used under these conditions, but their use will result in providing greater crossing clearances than required by the rules.

[1] As tables are used in this discussion as well as in the code, and as reference is frequently made to code tables in the discussion, some method of identifying the source seemed desirable. Consequently, it was decided to add a prefix "D" to all table numbers included in the discussion; thus table 4 will be found in H32 (the code) but table D4 will be found in the discussion. As the only figures used in H32 are those of "Conductor Conflict" and "Structure Conflict" in sec. 1, and as these are not numbered, no such identification of figures is necessary.

Study of the sag-increase curves for all conductors indicated that although they differed widely, the sag increase was greater for the smaller conductors than for the larger conductors, and that in order to avoid unduly penalizing the larger conductors the clearance requirements should take account of this fact. This led to the definition of "small" conductors given in the rule and the different clearance increments specified for small and large conductors.

In order to insure a margin of safety, it was decided that there should be at least a 1.5-foot clearance at wire crossings with total sag in the upper conductors and initial unloaded 60°F sag in the conductor at the lower level. Additional curves were therefore drawn of the sag increase plus 1.5 feet plotted as a function of span length. Figure 3 illustrates such curves, and for the sake of clarity only four are shown, two for large conductors in the medium-loading district and two for small conductors in the heavy-loading district. The broken lines in this figure show the clearance increments decided upon for the heavy- and medium-loading districts. It is evident from this sketch that as long as the curves are to the right of the applicable broken line, the crossing clearance in any span under the assumed conditions will always be at least 1.5 feet. The clearance-increment lines selected are such that this result is substantially obtained for all conductors. It is also apparent from this sketch that in any span where the sag increase is not over 2.5 feet (that is, where the sag increase plus 1.5 feet is not over 4 feet) no increase in clearance because of span length is necessary at crossings where the basic clearance required by table 3 is 4 feet. This provided the basis for determining the span lengths specified in rule 233,A,2 beyond which increased clearances must be provided.

Use was made of the maximum-sag-increase figures in setting limits on the amount of additional clearance that would otherwise continue to increase indefinitely with each 10 feet of increase in span length. As indicated in the footnote to table D13, in Appendix 2A, the maximum sag increases of certain of the smaller conductors cannot be determined from existing data. Most of these indeterminate cases occur in the light-loading district. Until these values are available, clearance-increase limits for these conductors could not be established and it will, therefore, be necessary to add the applicable clearance increment as computed for the length of span involved in each such case.

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Limiting the additional clearance in the more usual cases to 75 or 85 percent of the maximum sag increase, depending upon the loading district, is empirical but is regarded as insuring adequate clearances. It should be noted that the span length at which the maximum sag increase for a given conductor occurs bears no relation, unless by coincidence,

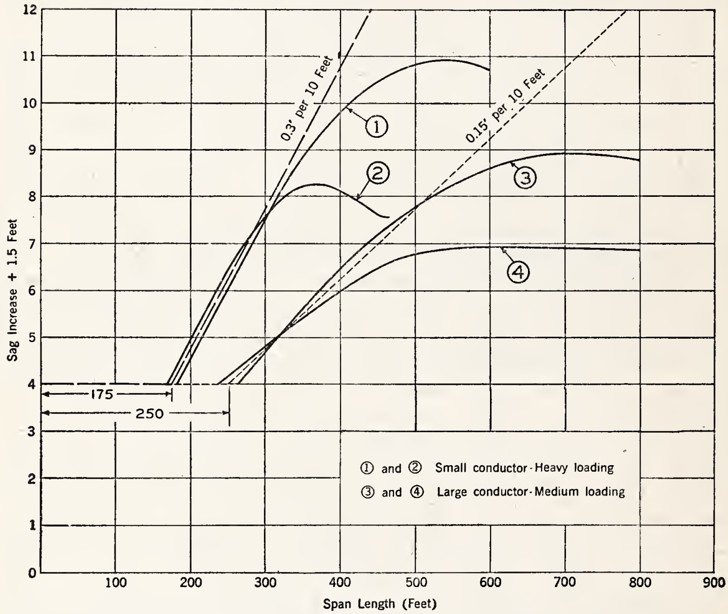

FIGURE 3.—*Relation between sag increases and clearance increments.*

to the length of span for which a required clearance is being determined.

The point of maximum sag in a conductor, even where its supports are at different elevations, is approximately at midspan. Sag increases are less at other points in the span than they are at midspan, and smaller clearance increases are therefore permitted for crossings at such points. This is accomplished by means of the reduction factors, as determined from the catenary curve shown in fig. 18, Appendix 2C, given in the rule for different points of crossing expressed in percentage of crossing-span length.

According to rule 233,A,1 the crossing clearances specified in the code are minimum values that must obtain at 60° F., no wind, with the upper conductor at its final unloaded sag. In constructing new crossings, or in determining clearances before the upper conductors have been subjected to load and therefore still have initial unloaded sags, the proper values will be the minimum clearances given in the rules plus the difference between initial and final unloaded sags for the upper conductors. In order to facilitate the making of this correction, tables D14 to D20, Appendix 2B, have been prepared giving the differences between 30°, 60°, and 90° F, initial unloaded sags and 60° F final unloaded sags for the more commonly used conductors.

It is obvious that there should be some increase in clearance as the voltage of the conductors increases. Table 3 gives definite steps of clearance increase for voltages up to 50,000. Above this voltage a uniform increment per 1,000 volts is applied.

A few inches displacement of the free end of a suspension insulator toward the crossing span it supports might reduce the clearance of such a span by as many feet. If, however, there are suspension insulators at both supports, only the differential displacement is involved, and this will be relatively less than with suspension insulators at one support only. The rule ignores the resulting change in sag, although it is possible that in some cases the change will be material. The greatest effect is produced by a broken conductor at a nearby point. The rules are so worded as to modify the clearances to provide for these conditions.

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

A. Clearances from Conductors of Another Line.

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

B. Clearances from Supporting Structures of Another Line.

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

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

C. Clearances from Buildings.

The efficiency of firemen is much reduced when they are hampered by the proximity of electric conductors. This is due to mechanical interference with ladder raising and hose handling, as well as to the fear of serious electrical shocks. The clearances indicated will be sufficient usually to permit effective work of firemen. (See figs. 4 and 5.)

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

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

D. Clearances from Bridges.

The clearances given are designed to prevent contact of supply conductors with bridges by swinging in the wind or by sagging with ice or high temperature. They are also intended to provide adequate clearances for painters and others who may have to work about ordinarily inaccessible parts of bridges. The clearance required from accessible portions of bridges (3 feet for voltages less than 8,700) is very moderate and is usually exceeded in good practice. Three feet is probably sufficient for horizontal distance from wing walls readily accessible only to workmen, but

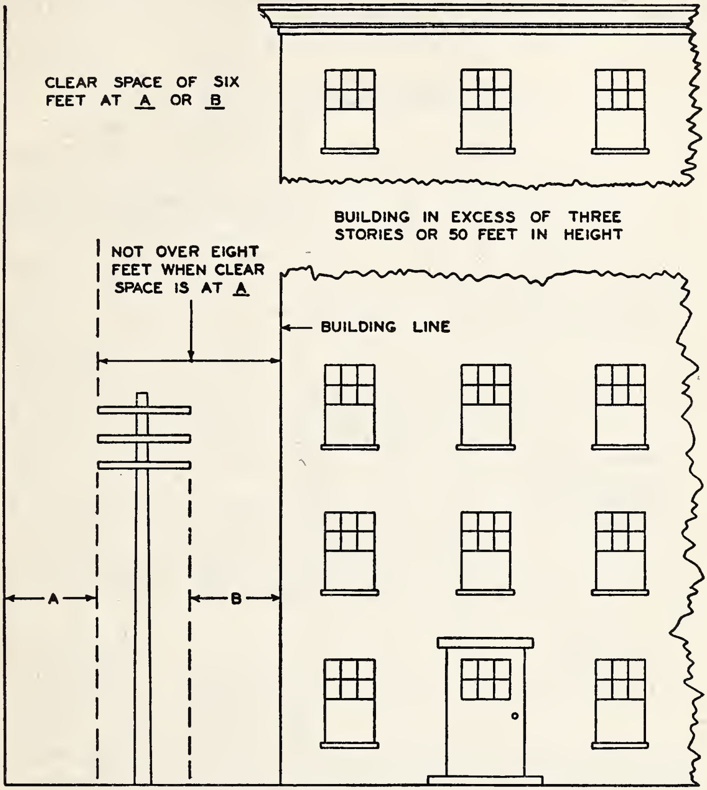

FIGURE 4.—*Clearances of conductors from buildings to provide fire-ladder space.*

insufficient in many cases for even horizontal distance from spaces accessible to children, and is always insufficient for elevation above spaces accessible to the public, for which see rule 232. The necessity for warning signs is apparent, since persons will often trespass on parts of bridges and other structures where they are not permitted to go. It is customary to attach a conductor directly to the supports of bridges, and as these are generally fairly close together and the sags are consequently quite small,

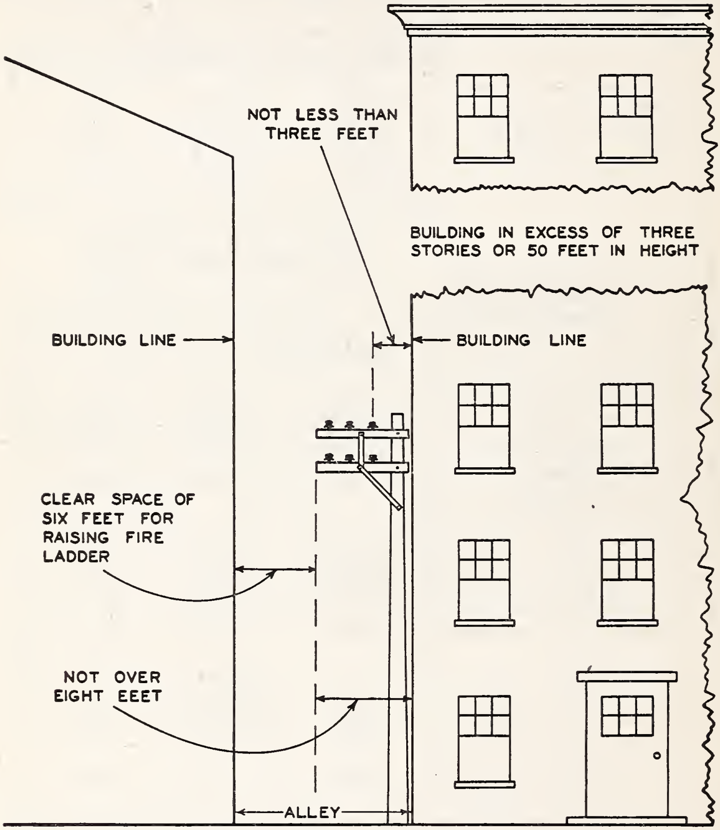

FIGURE 5.—*Clearances of conductors from buildings to provide fire-ladder space.*

less separations than are required in other locations may be used. (See rule 235,C.)

Note 5 to table 5 covers the situation where conductors passing under bridges are adequately guarded against contact by unauthorized persons and can be de-energized for maintenance of the bridge. In this case the question of hazard to persons is removed and the bridge assumes the characteristic of any other supporting structure. The additional increment of clearance equal to one-half the final unloaded sag of the conductor at the point of clearance was added to provide adequate clearance at every point whether the crossing is made with or without attachment to the bridge.

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

A. Separation Between Conductors on Pole Lines.

The values specified in table 6 for the separation of conductors are minimum values only and apply where the spans are short and the sags small. Where the sags are greater it is, of course, necessary to increase the separations to provide sufficient clearances in the span when the conductors swing in opposition to each other. This is provided for in tables 7 and 8. Where the conductors operate at voltages in excess of 8,700, the separation is increased by an increment which is determined by the sparking distance in air. This distance, however, is not directly proportional to the voltage, but the increment has been made so in order to simplify computations and provide a working value.

The conductor separations called for according to sags are intended to provide sufficient space for workmen on poles and prevent swinging contacts between the conductors, except for the smallest permissible conductors, which swing about more in the wind because of their relatively large sags.

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

When suspension insulators are used and are not restrained from motion, such conditions as changes in temperature and ice loading would cause the free end of the insulator to move in the direction of the line. A movement of only a few inches of the free end of the insulator would, in some instances, increase the sag of the conductor by as many feet. The minimum clearances of conductors attached to suspension insulators are those clearances at the extreme position to which the insulator is displaced.

It also may be possible for a 60-mile wind blowing at right angles to the line under some conditions of loading to swing the insulator 45° from the vertical position. The values in table 6 being minimum clearances should be complied with even when suspension insulators are used and are displaced 45°.

4. CONDUCTOR SEPARATION—VERTICAL RACKS.

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

Where conductors are supported by racks, the vertical separations specified in this rule are considered satisfactory values for voltages less than 750. However, it is assumed that due care is exercised when the conductors are installed in order to have the same separation in the spans.

5. SEPARATION BETWEEN SUPPLY CIRCUITS OF DIFFERENT VOLTAGE CLASSIFICATIONS ON THE SAME CROSSARM.

In many cases, because of lack of vertical space on the poles or the necessity for stringing additional conductors, it is impossible to install more arms in order to provide proper separation vertically between the conductors of different classification. In order to provide safe construction under these conditions the requirements of this rule will permit two circuits or sets of conductors to occupy the same crossarm in the five cases listed, provided a sufficient separation is maintained. (See fig. 6.) The first two cases may be applied to communication circuits used in the operation of supply lines. The classification referred to is that of table 11—750, 8,700, and 15,000 volts being the division points between classes.

The arrangement of conductors shown in case *d*, figure 6, is not permitted for ordinary constant-voltage distribution circuits, but is intended to provide only for series lighting and similar circuits which are normally dead during the day and which would, therefore, not present a hazard to men working on the lower-potential circuits beyond them during daylight hours. Where it is customary to test series arc circuits during the day, it may not be advisable

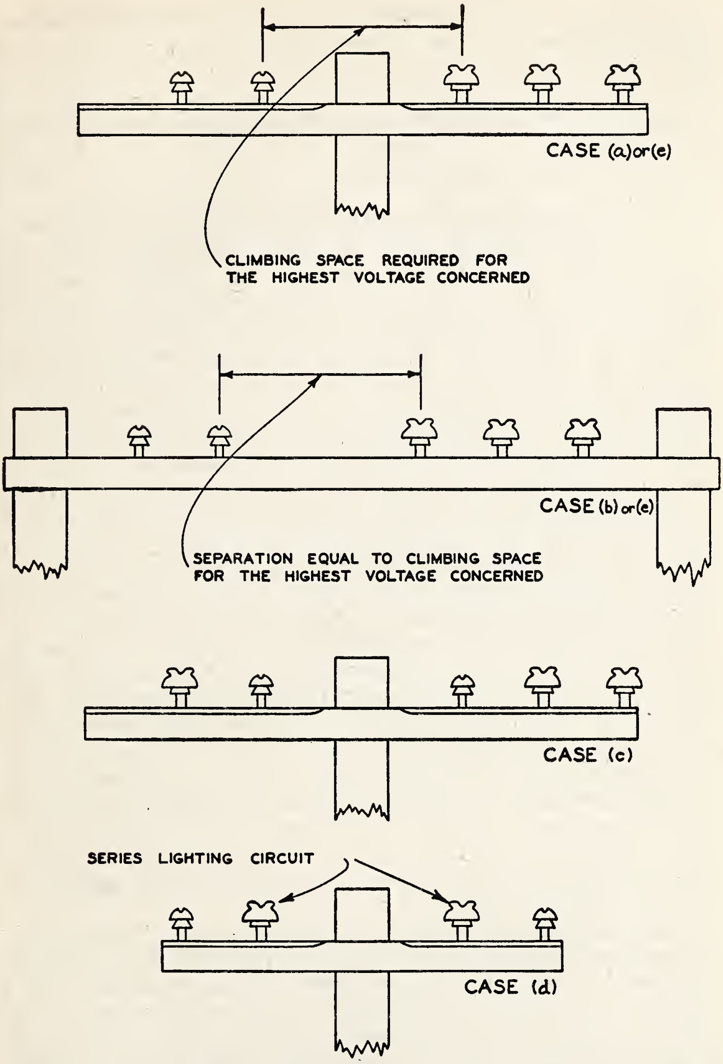

FIGURE 6.—*Permissible arrangements of supply circuits of different consecutive voltage classifications on the same crossarm.*

Case letters above refer to corresponding items under rule 235, A, 5.

to employ this type of construction unless the workmen take proper precautions.

236. Climbing Space.

D. Location of Supply Apparatus Relative to Climbing Space.

See discussion of rule 286,B.

E. Climbing Space Through Conductors on Crossarms.

The same climbing space is to be maintained for communication conductors as is required for supply conductors immediately above them when both are attached to the same pole with a maximum of 30 inches. This requirement is made not so much for the hazard due to the communication conductors alone, but for the hazard that might exist if a fallen supply conductor at some distant point were in contact with one of the communication conductors. In this case a high potential might exist between the two pole conductors of the communication circuit which could cause a serious accident to a lineman required to crowd through conductors having a reduced climbing space. Other considerations are that supply linemen will not get their feet against communication wires; and that they will not injure them in climbing through.

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

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

G. Climbing Space for Longitudinal Runs.

It has become common practice in many localities to place the low-voltage conductors, which are generally used for supplying services, vertically on racks or brackets, close to the poles, thus practically cutting the climbing space in half. While such construction provides comparatively easy and simple methods for the attachment of services, it requires readjustment of other construction to avoid obstructing the workmen climbing up and down the pole and, unless other arrangements in the locations of the adjacent conductors are made, constitutes a hazard. In order to comply with the provisions of the rules without variation, these racks are occasionally placed on extension pieces. In lieu of this, the nearest supply conductors on crossarms may be 4 feet from the rack, or the conductors on the adjacent arms may be so installed as to provide the full climbing space on one side of the rack. Where attachment of conductors close to the pole seems advisable, the racks should generally be on only one side of the pole for uniformity, and the climbing space should generally be carried vertically at the other side. The climbing space between any two wires is required, however, by the rule, to be carried vertically at least 40 inches above and below them, and any shifting of the climbing space from side to side must, therefore, be done in steps not less than 40 inches apart.

H. Climbing Space Past Vertical Conductors.

This rule shows that when the climbing space is changed from one side to a corner of the pole, as illustrated in figure 7, the pole itself, or conductors enclosed in a conduit or protected by a molding when located in the corner of the climbing space, are not considered as an obstruction.

237. Working Space.

Sufficient clear working space must be provided between the conductors supported on adjacent crossarms to permit linemen to work safely upon the conductors supported by a pole or structure. The vertical and horizontal clearances called for in the rules are generally between conductors rather than between pins or crossarms. (See fig. 8.) However, in cases where the crossarms fulfill the vertical-clearance requirements, but owing to the use of different types or sizes of insulators or different manners of attachment the clearances between the conductors themselves are slightly

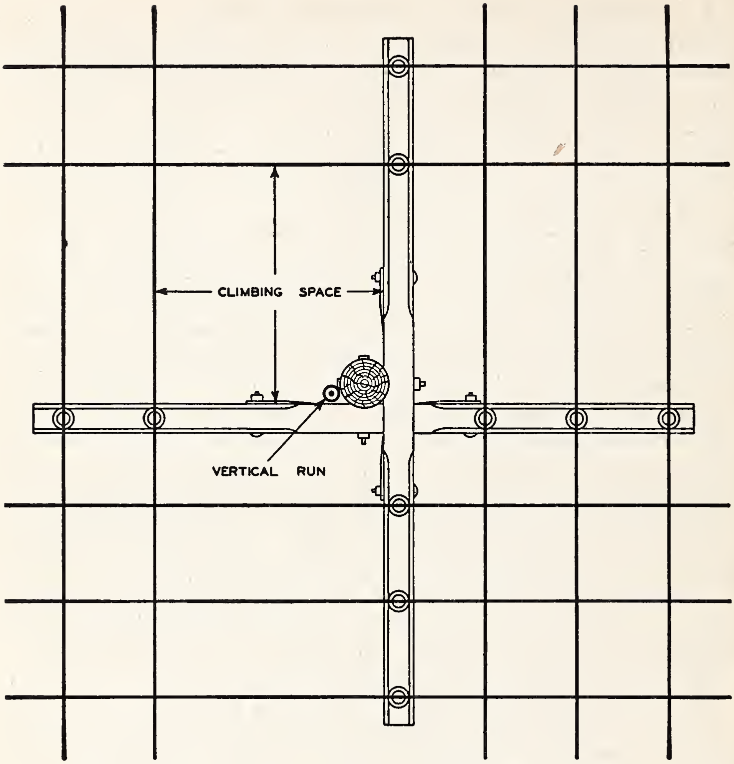

FIGURE 7.—*Example of unobstructed climbing space.*

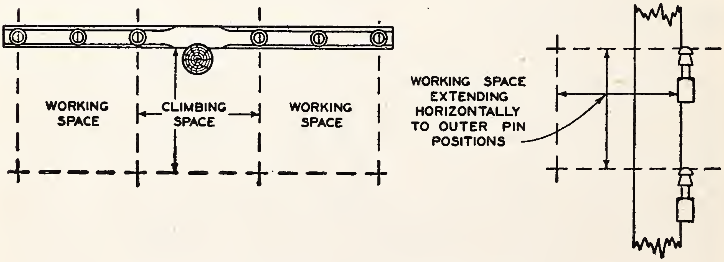

FIGURE 8.—*Working space.*

reduced, the requirements of the rule will be considered as having been met.

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

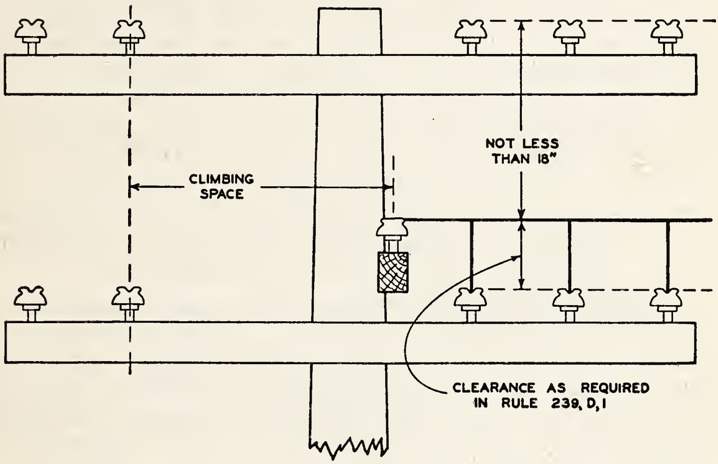

FIGURE 9.—*Obstruction of working space by buckarm.*

install additional arms or other means to support the conductors in order to provide the proper clearances and separations.

D. Location of Buckarms Relative to Working Spaces.

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

The rules require the provision of climbing space, in accordance with rule 236, under all circumstances. To accomplish this, exception is made by rule 236,F, to the general requirement for horizontal separation of wires at supports, under certain conditions. For voltages not exceeding 8,700, an exception has been included in this edition of the code to permit a 12-inch instead of an 18-inch working space in construction involving not more than two sets of line arms and buckarms when certain prescribed safety measures are practiced. Where crossarms have the usual 2-foot spacing and the 18-inch working space is provided, the buckarm is placed close to one of the line arms, as shown in figure 9. This should be the line arm carrying the conductors which are connected to conductors on the buckarm. The vertical and lateral conductors will then not obstruct the free 18-inch space which constitutes a reduced working space. One set of conductors can be worked on from below and the other from above.

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

A. Vertical Separation Between Horizontal Crossarms.

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

It may be necessary to increase these vertical clearances under some conditions, as, for instance, when conductors on different crossarms are strung with widely different sags or where wires on different crossarms have materially different sag increases under load or high temperatures. The values given in table 11 are minimum values, except as covered in the notes to the table.

B. Vertical Separation Between Line Conductors on Horizontal Crossarms.

Where supply conductors of the same circuits are arranged vertically on separate crossarms, the vertical separations are determined by the highest voltage concerned.

Although table 11 requires in some cases a greater vertical spacing between conductors in different consecutive voltage classifications than between conductors of the higher voltage, it should not be interpreted as applying to the condition shown in figure 10, where the conductors of different voltages are on opposite sides of the pole. In this arrangement the vertical spacing is that for the higher voltage.

A minimum separation of 40 inches between communication and supply conductors up to 8,700 volts between con-

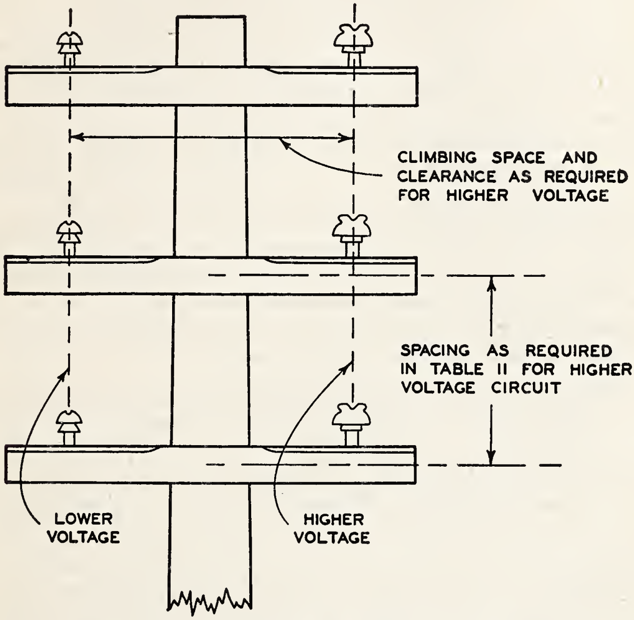

Figure 10.—*Vertical arrangement of circuits.*

ductors on joint poles has generally been considered a proper figure. Experience has shown that with span lengths of 150 feet or less, such as are found in most joint construction, this clearance at the pole is sufficient to minimize the possibility of accidental contacts between the usual types of supply wires and communication cables in the spans even when the supply wires are loaded with ice. This separation is also sufficient to take care of situations where ice may fall or be jarred off communication conductors in the lower position while the supply conductors are still under load. Such separation also provides a clear working space between the two types of facilities so that linemen working on supply wires at about waist level will have clear leg room below such wires and communication linemen will also be provided with clear headroom while working on their facilities.

Experience indicates that adequate separation at the supports is a fundamental requirement for safety where joint use is employed. While the rules provide for a minimum separation of 40 inches, it may, of course, be desirable to increase this separation, where greater separations are readily practicable, where spans exceed 150 feet in length, or where unusual types or sizes of conductors are used.

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

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

A. Location of Vertical or Lateral Conductors Relative to Climbing Spaces, Working Spaces, and Pole Steps.

To facilitate uniformity in the arrangement of conductors and equipment on a pole, it is usual to designate one semicircumference or quadrant of the pole as the climbing space. Where poles are used jointly by supply and communication conductors, it is customary to designate the sidewalk as the climbing side, leaving the street side clear for the attachment of lamp leads, and, where a street railway is also concerned, for the attachment of span wires or brackets.

B. Conductors Not in Conduit.

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

C. Mechanical Protection Near Ground.

Grounding wires that have become broken by traffic or other cause may have lost their effectiveness in protecting the circuits or apparatus to which they are connected. Thus a mechanical protection is essential in certain instances to guard against such breakage.

D. Requirements for Vertical and Lateral Supply Conductors on Supply-Line Poles or Within Supply Space on Jointly Used Poles.

The only persons concerned when supply conductors pass through the space occupied by supply conductors or on poles occupied only by supply conductors are linemen who are or should be entirely familiar with the hazards incidental to the voltage concerned. The requirements of rule 239,F are, therefore modified.

F. Requirements for Vertical Supply Conductors Passing Through Communication Space on Jointly Used Poles.

Vertical supply conductors carried through a space occupied by communication conductors require special protection, especially where the voltage is high. Linemen who make repairs or extensions to communication circuits cannot well avoid coming into contact with such supply conductors, and the latter must, therefore, be protected where they are liable to be touched by such linemen. The distance to which the insulating or grounded enclosure extends below the communication conductors is determined by the position of the lineman's spur when working on the wires.

Where street-lighting circuits or low-voltage services are concerned, the former being alive normally only during the night, the enclosure specified above may be omitted, provided the conductors are insulated and properly supported, so that a lineman climbing the pole will be able to do so without touching the conductors. This is particularly true where pole steps are installed on poles carrying such conductors. The distance specified, 5 inches from the pole surface or from the pole steps, is considered sufficient to permit good footholds or handholds and still prevent contact with poorly insulated wires.

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G. Requirements for Vertical Communication Conductors Passing Through Supply Space on Jointly Used Poles.

Communication conductors passing through a space occupied by supply conductors require an insulating protection because they are practically grounded and therefore are hazardous to supply linemen.

SEC. 24. GRADES OF CONSTRUCTION

240. General.

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

One element of hazard due to the existence of an overhead line is dependent on the voltage of the line. For the purpose of discriminating with respect to this element of hazard supply conductors have been divided into various classes according to the voltage concerned.

If a heavy communication lead is involved at a crossing, or on jointly used poles, under supply wires, the falling upon the former of a high-voltage supply conductor may spread trouble over a wide area. The high voltage may be brought into several communication offices and into many subscribers' premises thus bringing danger to many persons. Some protection is afforded, of course, by the usual communication arresters and fuses, protection being very reliable within more-or-less definite voltage limits. These limits are less than the operating voltage of some of the existing systems of distribution in large cities and much less than almost all transmission voltages.

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

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

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

Different requirements are properly made to alleviate different degrees of hazard. For supply lines, three different degrees of hazard are recognized with corresponding gradations in the minimum standard for construction, and these differences apply mainly to the strength of the supporting structures. The grades are designated as B, C, and N and for two of these grades specific strength requirements are provided. Grade B represents the strongest construction. For communication lines at crossings over railroad tracks, the grade of construction is designated as D.

In the fourth edition of the code, two other grades of construction were designated, namely A and E. Experience with the rules in that edition indicated that certain of the strength requirements for grade A could reasonably be modified to accord with those for grade B. In order to obtain greater simplification in preparing the fifth edition, former grades A and B were, therefore, combined and the new grade B established. Grade E has also been eliminated by appropriate changes in and additions to the rules for grade D.

The strength requirements for the various grades of construction are specified in section 26.

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

No requirements for provision of insulating coverings for conductors in overhead lines of any voltage have been made. While such coverings are sometimes an aid in preventing burnouts, the reduction of hazard derived from their use is problematical. Their use may even cause an added hazard for the higher voltages, because they deteriorate after being in service some years. Their use in this condition gives rise to a false feeling of security. Much more reliable and effective safeguards against the danger from fallen and crossed wires are the provision of proper wire clearances and separations and the maintenance of these clearances and separations by suitable minimum conductor sizes, sags, and strength of supports.

241. Application of Grades of Construction to Different Situations.

A. Supply Cables.

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

D. At Crossings.

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

E. Conflicts.

A distinction is made between conductor conflict and structure conflict, as will be seen by referring to the definitions. A structure conflict imposes requirements only upon the supporting structure and not upon those conductors not involved in the conflict. Conversely, if a conductor alone is conflicting, only it is thereby required to meet the corresponding obligations, and the structure which carries it may be of a lower grade.

242. Grades of Construction for Conductors.

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

For reasons already stated (see discussion of rule 240), a distinction is made in the requirements in urban districts and in rural districts. In each case the degree of hazard is determined by the voltage of the circuits concerned, and, when circuits of different voltage are placed on the same supporting structure, by the arrangement of the circuits with respect to each other.

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

B. Status of Railway Feeders and Trolley-Contact Conductors.

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

D. Status of Fire-Alarm Conductors.

For spans up to 150 feet the minimum sizes and sags given for communication wires crossing over main railroads should give ample safety to fire-alarm lines. However, since it is necessary that fire-alarm wires do not break, especially in cold or stormy weather when fires are most frequent, it is desirable that they be strung with sags considerably greater than those specified as minima in rule 262,I,4.

243. Grades of Supporting Structures.

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

SEC. 25. LOADING FOR GRADES B, C, AND D

250. General Loading Map.

Studies of data from the United States Weather Bureau and from the records of the wire-using companies as to the frequency, severity, and effect of ice and wind storms in various parts of the country, provide a basis for dividing the United States into three loading districts, shown on the map as heavy, medium, and light. Weather conditions do not, of course, change abruptly at the lines which have been chosen as the boundaries of these districts, nor is it possible to establish these boundaries precisely. Nevertheless, experience has shown that the year-in-and-year-out differences in weather conditions as between these general areas are sufficient to require recognition in establishing overhead construction rules.

Such changes as have been made from the map contained in the fourth edition of the code are based on studies of the additional weather data and experience accumulated since the fourth edition was published. The boundary lines between the loading districts have been chosen so that, as far as possible, they follow natural physical dividing lines or the boundaries of major political subdivisions already established and easily recognized.

While general boundaries are indicated in the States of California and Nevada, it is the intent that the detailed boundaries in these States will be as defined by the orders of the regulatory authorities in these States. It is known that storms of heavy-loading intensity occur in certain local areas in Washington and Oregon, and it is the intent that the boundaries of such localized areas be defined in the States themselves.

The following outlines in detail the boundaries between the various loading districts.

BOUNDARY BETWEEN THE HEAVY- AND MEDIUM-LOADING DISTRICTS

Beginning at the Atlantic seaboard, follow the 38th parallel of north latitude to Albemarle County, Virginia; follow the eastern boundaries of Albemarle, Nelson, Amherst, Bedford, Franklin, and Henry Counties of Virginia to the southern boundary of Virginia; follow the southern and western boundaries of Virginia to West Virginia; follow the western boundary of West Virginia to the Ohio River; follow the Ohio and Mississippi Rivers to the Arkansas State line; follow the northern Arkansas State line westward to the Oklahoma State line; follow south along the Arkansas-Oklahoma State line to the Red River; westward on the Red River to the intersection of the eastern boundary of Red River County, Texas; in Texas follow the eastern and southern boundaries of Red River County, the southern boundary of Delta County, the eastern and southern boundaries of Hunt County, the southern boundary of Rockwall County, the eastern boundary of Dallas County, the southern boundaries of Dallas, Tarrant, Parker, and Palo Pinto Counties, the eastern and southern boundaries of Eastland County, the southern boundaries of Callahan, Taylor, and Nolan Counties; north on the western boundaries of Nolan and Fisher Counties; west along the southern boundary of Kent County; north on the western boundary of Kent County to the intersection with the White River; northwest along the White

River to the northern boundary of Lamb County; west on the northern boundary of Lamb and Bailey Counties to the Texas-New Mexico State line; north on eastern New Mexico State line to the southern Colorado State line; west on the Colorado State line to the southeast corner of Costilla County, Colorado; follow northward along the eastern boundaries of Costilla, Alamosa, Saguache, Chaffee, Lake, Eagle, and Routt Counties in Colorado to the northern Colorado State line; follow eastward along the Colorado State line to the 106th meridian of west longitude; follow north on the 106th meridian of west longitude to the intersection with the 43d parallel of north latitude; follow east on the 43d parallel of north latitude to the eastern Wyoming State line; follow north on the eastern Wyoming and Montana State lines to the Canadian boundary.

BOUNDARY BETWEEN THE MEDIUM- AND LIGHT-LOADING DISTRICTS

From the Atlantic seaboard, follow the 33d parallel of north latitude across the States of South Carolina, Georgia, Alabama, and Mississippi to the intersection with the Boeuf River in Louisiana; then southwestward along the Boeuf River to the northern boundary of Caldwell County; along the northern and western boundaries of Caldwell County to the northeastern corner of Winn County; westward along the northern boundaries of Winn, Natchitoches, and Sabine Counties in Louisiana to the intersection with the Sabine River; south along the Sabine River to the northeastern corner of Sabine County, Texas; then in Texas along the northern and western boundaries of Sabine County, and the northern boundaries of Jasper and Tyler Counties to the intersection with the 31st parallel of north latitude; west along the 31st parallel of north latitude to the intersection with the Pecos River; then northwest along the Pecos River to the southern boundary of New Mexico and west on this State line to the ridge of the Guadeloupe Mountains; follow the ridge of these mountains to the intersection with the southern boundary of Chaves County, New Mexico; follow the southern and western boundaries of Chaves and Lincoln Counties to the intersection with the Sierra Oscuro Mountains; follow the ridge of these mountains north to the 34th parallel of north latitude; follow west along the 34th parallel of north latitude across New Mexico and Arizona to the southeastern corner of Yavapai County, Arizona; follow west and north along boundaries of Yavapai and Coconino Counties to the intersection with the Colorado River; follow westward along the Colorado River to the Nevada State line; follow north along the eastern Nevada State line to the 38th parallel of north latitude, then westward across the State of Nevada as described in the Rules of the Public Service Commission of Nevada; continue westward along this line to the center of California, then northwestward to the northwestern corner of California.

251. Conductor Loading; and 252. Loads Upon Line Supports.

It is, of course, impracticable to design overhead structures generally to withstand the most severe weather conditions that may occur anywhere within such a large area as a loading district. Furthermore, it has been found through experience that this is not necessary in order to provide a very high degree of safety, since coincident combinations of extreme ice and wind conditions occur very infrequently and then only in relatively restricted areas. Data on climatic loading have been collected for a number of years by various wire-using organizations, and these data were carefully reviewed in connection with this revision of part 2. The results of this review and the extensive experience of the wire-using companies have, therefore, been used as a basis for the selection of the loading assumptions contained in the rules, as well as for the delineation of the loading districts.

Construction meeting the strength requirements of the rules for grades B, C, and D has been found to provide a degree of safety in keeping with the conditions under which each of these grades is required. For any specific type of situation in a given loading district, the appropriate strength of construction based on this experience could be provided for in the rules either by the adoption of relatively severe loading assumptions combined with high allowable stress values, or through less severe loading assumptions and lower stress values.

In the second edition of the code, different degrees of loading for different types of situations, even in the same loading district were specified. In later editions, a single set of loading assumptions was used in each loading district, but different allowable stresses were specified in different rules for the same materials to take account of different degrees of hazard. This latter method simplified the rules but, because of the choice of relatively severe transverse-loading assumptions, necessitated the use of allowable stress values in some cases which were considerably out of line with those used for the same materials in other fields of engineering. The further studies made since the fourth edition was issued have also shown that wind pressures such as those formerly assumed for transverse loading seldom occur concurrently with the assumed ice conditions and then only in restricted areas.

As in the fourth edition of the code, a single set of loading assumptions has been specified in the fifth edition for each loading district for all of the types of situations covered. The transverse-loading assumptions have been reduced, the new assumptions having been chosen so that while they fall well within the range of weather experience these assumptions permit the use of allowable stress values more in keeping with usual engineering practice than the values in the previous editions of the code. The vertical-loading assumptions in the fourth edition have been retained. While the method of specifying conductor loading in the fifth edition differs from that in the fourth edition, substantially the same conductor-loading assumptions have been retained by the addition of the constants given in rule 251. In view of this fact, existing manufacturers' sag-and-tension charts which are based on the conductor-loading assumptions of the fourth edition may still be used without appreciable error, if they also meet the unloaded-tension limits specified in rule 261,F,4.

At the time of preparation of this, the fifth, edition of the code, considerably more data and experience had been accumulated by the wire-using companies of this country than were available when earlier editions were prepared. These data were considered at great length before the present rules were prepared. While there are a number of factors involved in the strength of an overhead line, it is not possible to include all of these items in the code if workable rules are to be prepared. The principal ones have been included, however, and carefully considered values assigned to them for the various grades of construction and loading districts covered. Under these circumstances, assumptions made in the code may not, in many cases, represent actual pressures and loadings encountered over a period of years in actual practice but they probably are a much closer approximation than values resulting from the use of rules given in previous editions and when used in conjunction with the allowable stresses specified in the rules, these loading assumptions will provide construction which experience has shown to be on the safe side in the several types of situations where grade B, C, or D is required. For situations other than those for which grade B, C, or D is specified, the adequacy of line construction can only be determined by examinations of experience and the local conditions involved.

The nomograph shown in figure 16, Appendix 1B, provides a graphic means for determining the conductor loading in pounds per foot under the revised loading assumptions. Figure 19, Appendix 3A, consists of a nomograph for determining the bending moment due to wind pressure on poles.

252. Loads Upon Line Supports.

B. Assumed Transverse Loading.

6. At angles (combined longitudinal and transverse loading).

In the past there have been some misunderstandings as to the interpretation of this rule, and it has been revised to clarify its intent in the calculation of the resultant loads upon structures, including guys, at angles. The rule enumerates the various loads that must be considered at angles and states how they shall be determined and combined. Experience has indicated that certain approximations may be made in this connection without appreciably affecting the over-all result. For instance, if the resultant load is taken to be the arithmetic instead of the vector sum of the several assumed loads, computation of the strength of angle supports is considerably simplified and a degree of accuracy in keeping with the accuracy of other assumptions is secured in all but very unusual situations. Also, assumption that a wind direction along the bisector of the angle will give the maximum resultant load simplifies the computations and does not introduce any appreciable error unless there is a wide difference in the lengths of the spans adjacent to the angle or in the number and size of conductors in these spans.

C. Assumed Longitudinal Loading.

Experience has shown that the placing of guys on wood poles of higher voltage lines may under many conditions so reduce the insulation provided by the poles that insulator failures and flashovers are more likely to occur on such guyed poles than elsewhere on the line. On the other hand, line failures of a character such that accidental contacts were prevented at wire crossings by the presence of head guys have been much less frequent than was formerly anticipated. The rules covering longitudinal strength requirements have accordingly been revised so as to give appropriate weight to these facts. If a line is built of the same grade of construction throughout, it is considered unnecessary to provide special longitudinal strength at intermediate points. At points where there is a change in the grade of construction—as, for example, where a crossing span has been built in a line which is not so strong elsewhere—it is recognized that a failure in the weaker portion of the line may affect the stronger portion, and hence the longitudinal load at such points is based upon the assumption that certain of the wires may become broken elsewhere. Where wires smaller than No. 2 AWG are carried, it is assumed that two-thirds of them may be broken. However, to assure protection in cases where there are also a number of larger wires on the pole or where there are no wires smaller than No. 2, a minimum load equal to the loaded tension in two of the largest wires is assumed.

In the case of supply conductors, the actual tension in the conductors corresponding to the existing sag is used in the computation of load. In the case of communication conductors at railroad crossings, definite tensions in the conductors in percent of ultimate strength are assumed for each loading area, since such conductors are not ordinarily given larger sags for the purpose of relieving the pull upon supports as is sometimes done with heavy supply conductors.

D. Average Span Lengths.

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

Tower lines in hilly country, where the span lengths may vary in a ratio as large as 4 to 1, require individual treatment.

SEC. 26. STRENGTH REQUIREMENTS

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

The fourth edition of the code contained requirements for grades A, B, C, and N construction. Experience obtained since that edition was issued indicated that grade A requirements resulted in stronger construction than necessary in most cases. For this reason, and also in the interests of simplifying the code, grade B requirements were amended to include certain of the former grade A requirements and grade A was omitted. Grade N is the designation given to construction which does not have to meet the requirements of any of the other grades. There are, however, a few strength requirements for grade N construction, such as limiting sizes of supply conductors.

In the rules, the mechanical strength of poles and similar structures is assumed to involve only three considerations, namely, they should be able to support the weight of the conductors when carrying ice of a specified thickness; they should have sufficient strength to withstand the pressure of the wind at right angles to the line; and they should have sufficient strength to withstand the pull in the direction of the line due to any tension in the conductors which is not balanced, as for instance, at a dead end. It is, of course, recognized that actual line failures usually involve complicated combinations of these and other types of loads, such as torsional loads set up by wire breaks, loads due to conductor oscillations and swaying of supporting structures, and many others. However, experience has shown that the strength requirements included in the rules, based on the simple assumption of the three types of load mentioned, will provide adequate over-all safety. (See fig. 11.)

By dividing the allowable stresses given in the rules into the ultimate stresses for the various materials, so-called "factors of safety" may be determined. These

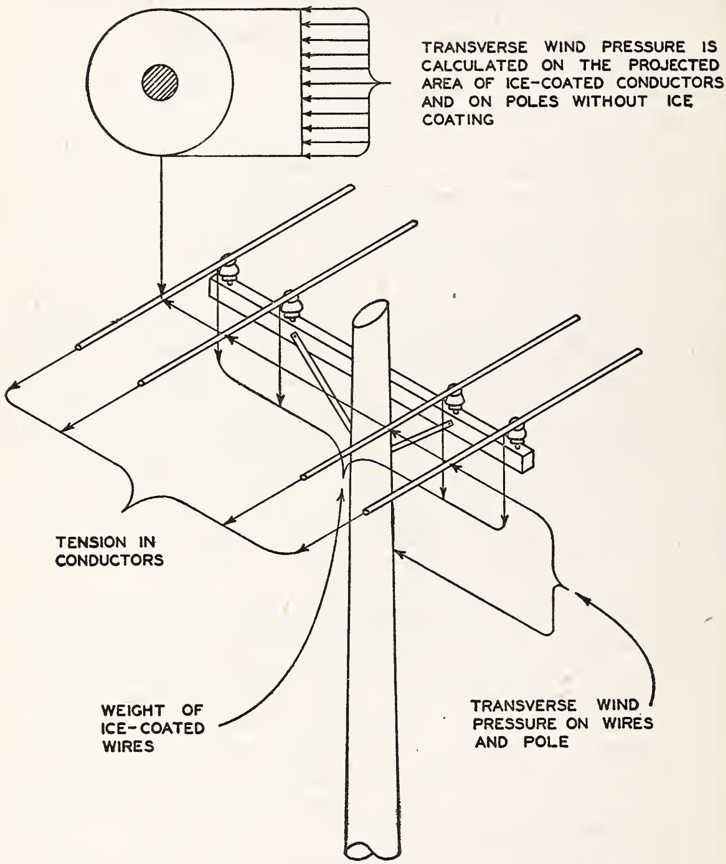

FIGURE 11.—*Forces producing load on supporting structures.*

"factors of safety" do not have the same meaning as in many other fields of engineering, where the loads and the resisting strengths of structures against such loads are more accurately known. Wood-pole lines are essentially flexible structures and their ability to withstand the varied and irregularly applied loading of wind and ice is proved by experience to be in excess of that calculated by the usual methods under code loading assumptions and strength requirements. In other words, the allowable stresses and loading assumptions contained in the rules are only a convenient means of providing construction which experience has shown to be adequate in the various situations where grades B, C, or D construction is required.

260. Preliminary Assumptions.

Certain influences which diminish the effect of the actual loadings have received careful consideration by reducing (below what would otherwise be considered proper) the assumed loadings and increasing the allowable stresses upon which are based the strength requirements of the several parts of the line; namely, conductors, fastenings, and pole or tower structures. The computation of stresses is usually made on the assumption that there is no deflection of supporting structures. However, such deflections occur, and the rule permits taking them into account under certain conditions. The conductors themselves exert a powerful influence in distributing the load along the line and in aiding the stronger structures to help support weaker ones.

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

261. Grades B and C Construction

A. Poles and Towers.

1. average strength of three poles.

The provisions of this rule are designed to permit considerable latitude in the construction of wood-pole lines. As stated elsewhere in the discussion of the code, there is proper justification for this allowance. It is a well-known fact that each pole in any supply line assists materially in supporting the poles adjacent to it, for the reason that the conductors themselves act as guys after the pole had deflected to a certain extent. However, it is important from the standpoint of safety that pole structures of sufficient strength be used at crossings over railroads or communication lines.

3. STEEL SUPPORTING STRUCTURES.

In this edition of the code, the required strengths of steel supporting structures are specified in terms of an "overload-capacity factor" of the completed structure. This makes it unnecessary to consider the stresses in individual members and greatly simplifies both the code treatment and the administration of the rules.

(d) *Strength at angles in a line.*—See discussion of rule 261,A,7.

(e) *Thickness of steel.*—The minimum thicknesses prescribed were selected with proper consideration of standard specifications and the best everyday practice. Steel towers and poles should be considered as permanent structures, and the employment of very thin members would tend to limit their life, especially under improper maintenance.

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

(h) *Protective covering or treatment.*—Steel and iron parts of towers and poles are subject to deterioration unless properly protected by galvanizing or some other equally effective treatment, or unless a good coat of weatherproof paint (such as graphite) is maintained. Galvanizing should be done by approved methods and be of such quality as to meet standard specifications.

4. WOOD POLES.

Where lines carried on wood poles are necessarily heavy, it is usually advisable to install poles giving some margin of strength over that required to just meet the rule. Preservative treatment, butt reinforcement, or other methods may be used to maintain the pole to a high percentage of its initial strength.

The extent of the deterioration of a wood pole is often difficult of determination. Where the butt has been subjected to insufficient preservative treatment, rot may develop in the interior of the pole, not visible from the outside, and while for a given loss of material it does not weaken the pole to the extent which butt rot on the outside of the pole weakens it, the pole may be weakened considerably or its life shortened.

Poles are often stubbed, instead of changed, especially in rural districts. If properly done, the results are effective, for the reason that it is generally possible to secure stubs of much better grade and much cheaper, on account of their

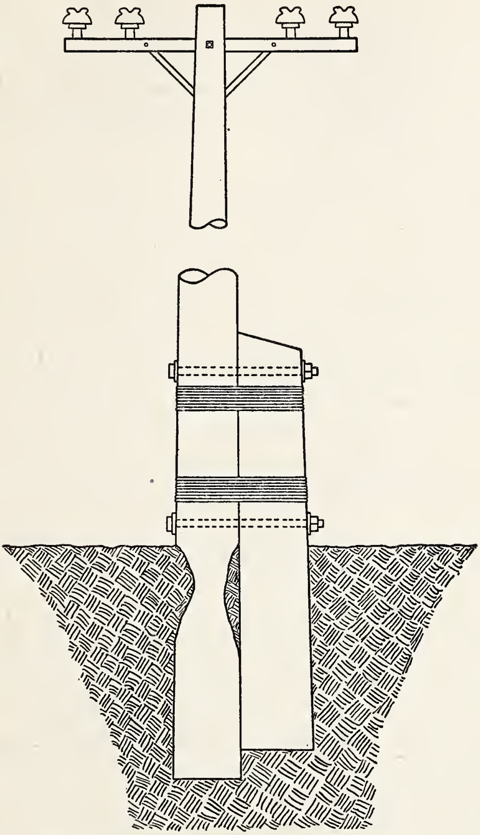

FIGURE 12.—*One method of stubbing to reinforce a deteriorated pole.*

short length, than full-length poles. The wrapping of the joint with wire, or the use of steel bands, in addition to bolting is recommended to prevent the bolts pulling through the pole. The stub should be placed beside the pole and not in front of it. (See fig. 12.) If badly decayed it may

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be advisable to cut off and remove the rotted butt of the pole.

The values for the ultimate strength of wood poles of different varieties included in the rules are in accord with present-day views. They are based on figures somewhat lower than the average value of breaking strength for a given kind of pole in order to insure that the actual strength of the majority of poles will fall above the assumed strength. It is to be supposed that the strength of an occasional pole will fall below that specified, but such a pole in a line, when flanked by poles of superior strength in spans of ordinary length, is not likely to fail.

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

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

5. TRANSVERSE-STRENGTH REQUIREMENTS FOR STRUCTURES WHERE SIDE GUYING IS REQUIRED, BUT CAN ONLY BE INSTALLED AT A DISTANCE.

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

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

6. LONGITUDINAL-STRENGTH REQUIREMENTS FOR SECTIONS OF HIGHER GRADE IN LINES OF A LOWER GRADE OF CONSTRUCTION.

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

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

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

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

7. STRENGTH AT ANGLES IN A LINE.

The fourth edition of the code was generally interpreted as requiring that poles at angles in a line withstand the arithmetic sum of the following loads without exceeding (at the ground line if unguyed or at the point of guy attachment if guyed) the allowable percentage of ultimate fiber stress specified for transverse loading:

(*a*) Wind on pole surface,
(*b*) Wind on conductors,
(*c*) Resultant of conductor tensions.

Experience with this method indicated that it resulted in excessive strength at angle supports, especially for relatively large angles, and after considerable study a modification was agreed upon and included in the fifth edition.

It was recognized that the three loads listed above must be taken into account. It was decided, therefore, to apply the allowable percentage of ultimate stress under transverse loading to the sum of (*a*) and (*b*), and to apply the allowable percentage of ultimate stress at dead ends to (*c*), before combining the three loads. This effectively accomplishes the desired result, because the amount of the reduction in over-all strength, as compared to the requirements of the fourth edition, then increases as the size of the angle increases and as load (*c*) thus becomes more and more controlling.

The loading assumptions for angles given in rule 252,B,6 specify the vectorial addition of the three loads. As a practical matter, however, the computations that this would entail are seldom warranted, since the degree of accuracy obtained under most conditions by adding them directly is in keeping with the accuracy of other assumptions necessarily involved.

Determination of the multiplying factors of 2 for grade B, and 1.5 for grade C given in the rule is simply a matter of reducing the two allowable percentages of ultimate stress to a common denominator. For grade B poles, for instance:

Allowable percentage for transverse loading is 25 percent (see rule 261,A,2), which means that transverse loads (*a*) and (*b*) above must be multiplied by 4.

Allowable percentage for dead-end loadings is 50 percent, which means that "longitudinal" load (*c*) above must be multiplied by 2.

$$\text{The combination then} = 4(a+b)+2c$$
$$= 2[2(a+b)+c].$$

The pole must then withstand this combined load without exceeding its ultimate fiber stress.

The study of this matter brought out the fact that there was some confusion as to whether combining loads (*b*) and (*c*) resulted in error due to twice taking into account the wind pressure on the conductors, since the same wind pressure that causes load (*b*) also contributes to the conductor tension in load (*c*).

The reason that adding these loads does not introduce an appreciable error goes back to the fact that the size of an angle in the conductor of a line is ordinarily measured by sighting along the line of the supports adjacent to the angle. This is not, of course, the same as the angle in the conductors on the corner support, since the effect of the wind is to displace the conductors out of the vertical plane passing through its two points of support. The angle in the conductors is obviously greater than the angle measured as above by sighting, and by an amount which depends upon the transverse wind pressure on the conductors. It may be said, therefore, that if the actual angle in the conductors is used in determining load (*c*), load (*b*) should be neglected. Otherwise, the wind on the conductors will, of necessity, have to be considered twice, as outlined above.

It is permissible, under the wording of rule 252,B,6, to take into account the reduction in conductor tension due to the angularity of application of the wind, which is usually assumed to be in the direction of the bisector of the angle. This is seldom done, however, because information as to the amount of the reduction is not available without special computations and because it would have little effect on the over-all result in most cases, particularly if the angularity of the wind is considered in determining load (*b*). (See sample computations in discussion of rule 261,C,5(b).)

B. Foundations.

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

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

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

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

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

C. Guys.

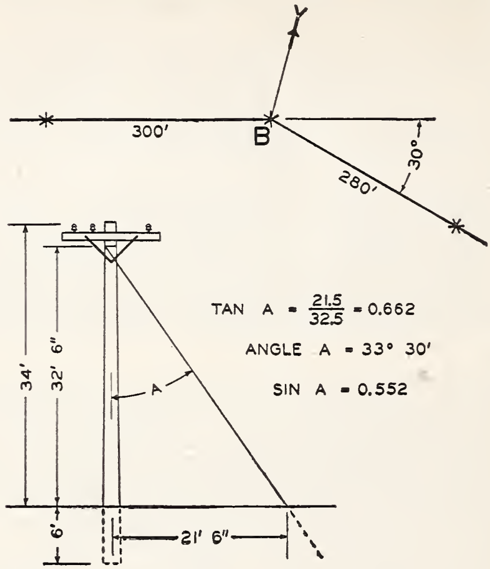
On account of the great flexibility of wood poles they may deflect considerably before developing much resistance to the transverse loads applied. Guys when installed properly are under initial stress and would fail before stretching enough to put much load on the poles. Thus, it is seen that the strength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

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

5. STRENGTH OF GUYS.

(*b*) *At an angle in a line.*—As covered in the discussion of rule 261,A,7, the total load at corners (other than those where dead-end construction is employed) consists of the sum of the loads due to wind on pole surface, wind on conductors, and resultant of conductor tensions. These three loads can most conveniently be added by first reducing them to equivalent horizontal loads acting at the point of guy attachment. The multiplying factor of 1.78 for guys is determined in a manner similar to that for multiplying factors for poles as explained in the discussion of rule 261,A,7. The following computations indicate how this rule may be applied in determining the strengths of guys required in several typical situations:

CASE 1.—*Strength of Transverse Guy at Angles*



Given: Grade B construction. Heavy-loading district. Three No. 2 (7-strand) ACSR conductors, 34 ft above ground on pole B. Maximum tension 60% of ultimate strength. Pole B, 40 ft, class 4, creosoted southern pine. 30° angle in line.

Find: Required strength of guy for pole B, in direction of bisector of angle.

NOTE.—As pointed out in the discussion of rule 252,B,6, certain assumptions may be made without introducing appreciable error in the calculations of the loads at angles. Advantage has been taken of these in the computation of loads *b* and *c* below.

a. Wind on pole:

From table D24, Appendix 3C, pole circumferences are 21 in. at top and 34 in. at ground line.

From the appropriate formula in Appendix 3A, moment at ground line (M) due to wind on pole

$=.018\ (2T+G)\ H^2$

$=.018\ (2\times 21+34)\ 34^2=1{,}580$ lb-ft.

Equivalent horizontal load at point of guy attachment= 1,580/32.5=48 lb.

b. Wind on conductors:

From table D1, Appendix 1A, the transverse load per foot of No. 2 (7-strand) ACSR conductor=0.439 lb per ft.

In this case, however, the wind in the direction of the bisector of the angle is 15° away from the perpendicular to the conductors. The transverse load, therefore, $=0.439\times\cos 15° =$ 0.424 lb per ft.

Moment at the ground line due to wind on conductors is

$$M=3\times 0.424\times\frac{300+280}{2}\times 34=12{,}542 \text{ lb-ft.}$$

Equivalent horizontal load at point of guy attachment= 12,542/32.5=386 lb.

c. Resultant of conductor tensions:

From table D1, Appendix 1A, the ultimate strength of No. 2 (7-strand) ACSR conductor is 2,790 lb. Maximum tension, therefore, is 60 percent of 2,790 lb=1,674 lb.

Moment at the ground line due to conductor tension (Angle in line 30°):

$$M=3\times 1{,}674\times 2\sin 15°\times 34=88{,}380 \text{ lb-ft.}$$

Equivalent horizontal load at point of guy attachment= 88,380/32.5=2,720 lb.

According to rule 261,C,5(b), loads a and b above must be multiplied by 1.78 before they are added to load c.

Total horizontal load at the point of guy attachment $=1.78(a+b)+c=1.78\times(48+386)+2{,}720=3{,}494$ lb.

Guy strength

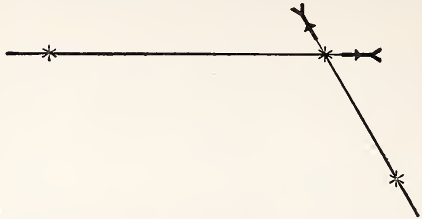
According to rule 261,C,5(a), the guy must withstand the total load without exceeding 66.7 percent of its ultimate strength, or in other words, the guy must withstand 100/66.7=1.5 times the total load without exceeding its minimum breaking strength.

Minimum breaking strength of guy

$$=\frac{\text{Total horizontal load}\times 1.5}{\sin a}=3{,}494/0.552\times 1.5=9{,}495 \text{ lb.}$$

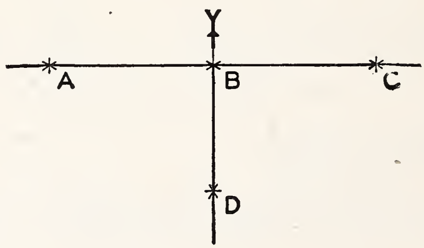
See table D10, Appendix 1A, for minimum breaking strength of guy strands.

CASE 2.—*Angle, Each Leg Guyed Individually*



Where a pole at an angle is to be supported by two guys, as shown in the sketch, the required strength of the guys is determined on the basis that they must support the dead-end loading assumed in rule 252,C,3, without exceeding the applicable allowable percentage of their ultimate strength specified in rule 261,C,5(a). No transverse loading need be considered.

CASE 3.—*"T" Corner*



The required strength of the guy on pole B shown in the sketch should be determined on the basis of whichever of the two following alternatives results in the stronger guy:

(a) Dead-end loading in accordance with rule 252,C,3 for all conductors in Span BD. This assumes wind perpendicular to Span BD.

(b) Dead-end loading for all conductors in Span BD, but with these conductors at tensions due to vertical loadings only, plus the transverse loading of rule 252,B,1,2, or 3 on pole B and the conductors in one-half of the sum of Spans AB and BC. This assumes wind perpendicular to AC.

It will seldom be necessary to consider alternative (b), because in all except very unusual cases (a) will require the stronger guy.

D. Crossarms.

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

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

In general, the longitudinal unbalancing will not be severe, except at angles and dead ends, unless a conductor fails. Transverse wind load is unlikely to break conductor fastenings, pins, or crossarms, even with heavy conductors in long spans. The vertical load at times becomes serious for small crossarms, but not for pins.

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

2. BRACING.

Bracing is, of course, generally necessary to withstand unbalanced vertical loads, as with oscillating conductors, men at work, or line equipment carried on the crossarms.

6. LOCATION.

The practice of attaching single crossarms on adjacent poles to opposite sides of the poles is to be commended, since it helps considerably to tie the wires in with the poles, and if a number of wires fail in a span the crossarms on the several adjacent poles will not be pulled off.

F. Open-Supply Conductors.

1. MATERIAL.

The use of noncorrodible material for overhead conductors is intended to prevent their falling due to deterioration.

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

By confining the use of soft copper to the heavier sizes—say, larger than No. 2, including railway feeders, the hazard will be much reduced. Railway feeders and secondary distribution conductors are frequently strung with less than maximum allowable tensions. Serious elongations of such conductors under wind and ice loads are not, therefore, to be expected, even if they are of soft copper.

2. MINIMUM SIZES OF SUPPLY CONDUCTORS.

The advantages in using the smallest allowable sizes of copper are frequently not so great as appear from the initial saving in copper. In regions where the load factor is low or the connected load small, a larger size of conductor may of course not be warranted by the greater assurance of continuity of service, the ability to care for load increases, the better voltage regulation, and the reduced maintenance charges. It may be seen, however, that such regions as really call for the smallest allowable conductors will usually be sparsely settled.

4. SAGS AND TENSIONS.

Although the conductors in the spans between poles may be required to conform to several grades of construction, the sags should be fairly uniform and so selected as to provide a tension within proper limits, for all sizes of wires in spans where grades B, C, or N construction are likely to occur simultaneously. Sags should be determined after careful consideration of operating experience in maintaining service and providing safety, together with a study of the observed mechanical characteristics of conductor materials under operating and test conditions. Requirements of construction practice make it necessary that sags in adjacent spans of different lengths should be such as to provide approximately equal stresses in the conductor in the different spans at the time of stringing. The sags should also conform reasonably with the requirement frequently met in cities and specified in many franchises that the sags of all conductors of a span should be about the same, regardless of conductor size, for the sake of appearance of the pole line and to prevent any substantial reduction of clearance due to conductors at a higher level sagging more than those below.

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

While large conductors may theoretically be strung to a less sag than smaller ones without exceeding their elastic limit when loaded, the tendency in practice in general city construction is to use larger sags than are employed for the smaller wires. This was shown by a large number of measurements made by this bureau. There are several reasons for this: (1) Railway feeders and other heavy conductors if strung to small sags would impose undue stress on poles and fastenings particularly at angles, dead ends, and other points of unbalanced tension; (2) Heavy conductors do not swing in the wind as readily as do light ones, and the need for small sag is therefore not so great. Furthermore, where heavy feeders are run on the same poles with other conductors they usually occupy the lower crossarm, where an excessive sag will increase rather than reduce the clearance from other wires.

G. Supply Cables.

1. SPECIALLY INSTALLED SUPPLY CABLES.

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

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

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

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

(d) *Cable insulation.*—As the supply cable is generally covered with a metallic sheath or armor, a superficial inspection of the exterior of the cable is not sufficient to determine its insulating strength. This is generally determined by applying for 5 minutes a test voltage equal to twice the operating voltage. This test has been considered sufficient to indicate an adequate operating factor of safety and to take care of voltage increases occasioned by surges or other disturbances.

H. Open-Wire Communication Conductors.

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

K. Short-Span Crossing Construction.

There are certain special construction specifications for crossings sometimes employed in practice which have for their purpose the reduction of the hazards involved and of the costs of construction and of the possible complications where a different grade of construction is required at the crossing. One of the most common of these special crossings is that employing a very short crossing span and making use of supporting structures at the crossing high enough to prevent the conductors, in case of accidental breakage, from coming in contact with the line crossed. This feature eliminates the minimum requirements for the conductors themselves, but the transverse and longitudinal strengths of the supporting structures are not affected, and, in addition, properly grounded guards must be provided to prevent, in case of breakage, the much longer conductors in the spans adjacent to the crossing span from coming in contact with the conductors crossed over. It is questionable, however, even with this construction, whether any particular reduction in cost is obtained in view of the necessity for higher structures and the possible additional supporting structure which may be required. (See figs. 13 and 14.)

L. Cradles at Supply-Line Crossings.

The reasons for recommending against the use of cradles are as follows: (1) The supporting structures must have transverse and longitudinal strength sufficient to carry the additional load due to the cradle. This is considerable, as the cradle must be substantially constructed of heavy material in order to be efficient and to carry the ice and wind loads to which it may be subjected. (2) The structures must have a height sufficient to provide proper clearance between the cradle and communication conductors crossed.

262. Grade D Construction.

The fourth edition of the code contained requirements for grades D and E construction for communication lines

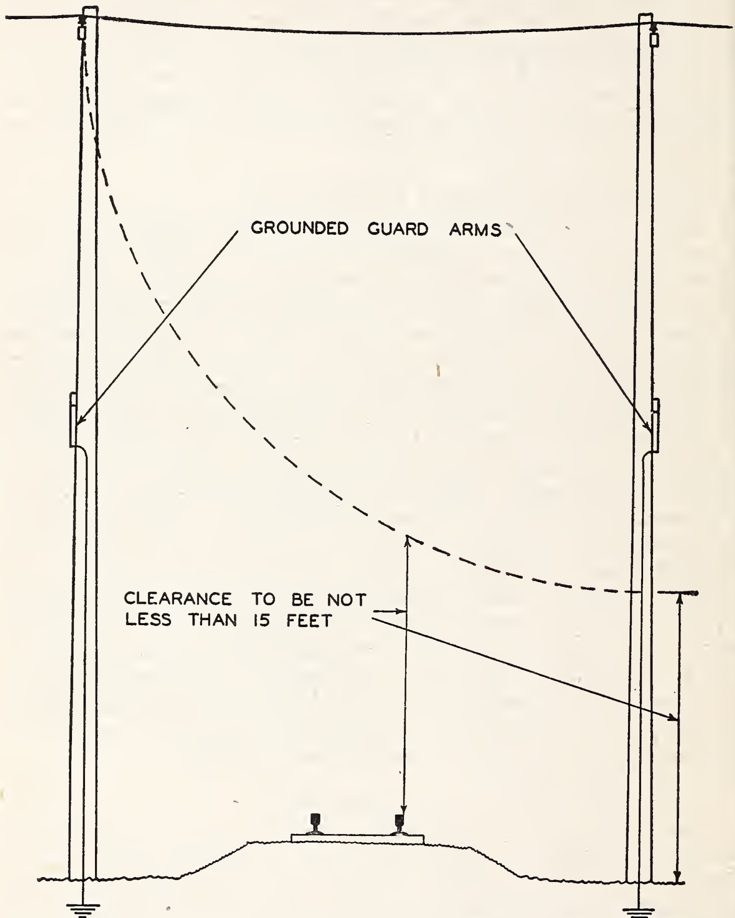


Figure 13.—*Special short-span crossing construction—supply lines over railways.*

crossing railroads. In the interest of simplification, grade E has been omitted from this edition of the code and the few requirements formerly applying to grade E construction have been introduced into the rules as exceptions to grade D requirements.

There is one basic difference in the hazards due, respectively, to supply and communication lines at railroad crossings. Supply lines present a mechanical hazard due to falling wires and poles, as well as an electrical hazard due to high voltage; hence, fairly large wire sizes are specified as minimums to prevent supply wires from breaking except under very unusual conditions. On the other hand, with communication lines where supply lines do not conflict, only the mechanical hazard exists; namely, that of poles or

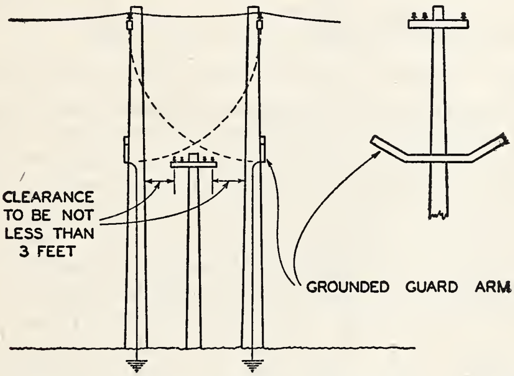


FIGURE 14.—*Special short-span crossing construction—supply circuits over communication circuits.*

wires falling on and interfering with railroad dispatch wires, or wires sagging so as to intercept men riding on top of the cars. Since the broken wires will usually clear the railroad dispatch wires without seriously injuring them, the crossing wires are permitted to be strung so that under the worst (unusual) conditions the wires may break and relieve the poles rather than pull them down.

A. Poles.

3. STRENGTH REQUIREMENTS FOR POLES WHERE GUYING IS REQUIRED, BUT CAN ONLY BE INSTALLED AT A DISTANCE.

Although this is not a desirable way of guying a crossing pole, it is considered as a reasonable alternative where it

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is impracticable to guy the crossing pole, since some of rigidity given thereby to the guyed structure will be transmitted to the crossing poles through the head guy, the amount transmitted depending greatly on the tautness of this head guy and the rigidity of the guyed structure.

4. POLE LOCATIONS AT CROSSINGS.

It is desirable that the crossing span be in line with the adjacent spans so as to make it comparatively easy to determine the resultant loads on the poles and also to compensate for them by proper guying. Keeping the line free from overhanging trees (especially dead and partly decayed trees) will, of course, help eliminate the possibility of wires breaking in a span adjacent to the crossing and thereby putting an excessive stress in the head guys.

8. POLES LOCATED AT CROSSINGS OVER SPUR TRACKS.

Lines which parallel railroads frequently cross spur tracks leading to manufacturing plants or warehouses, etc. There are consequently an extremely large number of such crossings. The installation of side or transverse guys under these conditions would, in general, produce a very complicated system of overhead guys and stubs. The necessity for such guys is but very little greater than elsewhere along the paralleling line which conflicts with the tracks practically throughout its length. The only additional hazard at the crossing over the remainder of the line is the possibility of a wire falling. The wire sizes, however, are those required for grade D crossings under other conditions.

263. Grade N Construction.

A. Poles and Towers.

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

This rule has been expanded to include requirements for keeping poles and stubs as far as practicable from the traveled portion of state and federal highways, for minimizing the number of wire and cable crossings over such highways and for the maintenance of lines and equipment which are within falling distance of the traveled portion of these highways.

D. Supply-Line Conductors.

1. MATERIAL.

In choosing the material for supply conductors consideration should always be given to the question of excessive corrosion of that material in the particular locality. Iron or steel wires near a seashore where considerable moist salt air is brought in contact with them will often corrode so rapidly as to become dangerous if only ordinary maintenance is given them. When used for overhead conductors, iron or steel wires should always be protected from corrosion by a recognized process.

2. SIZE.

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

Hard- or medium-drawn copper is nearly twice as strong as soft copper and a somewhat smaller size is therefore permissible.

Steel wire is as strong or stronger than hard-drawn copper, but since it will generally corrode faster, a slightly larger size is required as a minimum.

E. Supply Services.

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

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

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

H. Cradles at Supply-Line Crossings.

See discussion of rule 261,L.

SEC. 27. LINE INSULATORS

274. Test Voltages.

This rule gives the minimum values for dry flash-over test of the insulators used on lines of various voltages. The nominal voltage values in this table were changed from those given in the fourth edition in order to give recognition to values generally accepted throughout the industry. The table does not include all the commonly used voltages. An appropriate change in the column heading was also made to be consistent with the revised voltage values.

276. Selection of Insulators.

B. Insulators for Single-Phase Circuits Directly Connected to Three-Phase Circuits.

This is a new rule in the fifth edition of the code. It specifies the practice to be followed in selecting insulators for single-phase taps taken from three-phase circuits, either grounded or ungrounded, where such taps are not made through isolating transformers.

277. Protection Against Arcing.

The basic requirement for insulators is contained in this rule, which is a general statement of the engineering principles involved. It is not specific and thus permits sufficient latitude in designing a supply line to meet all the various conditions that must be taken into account.

278. Compliance With Rule 277 at Crossings.

For the reason that rule 277 is general and not specific, rule 278 has been included with seven alternative methods, any one of which will be considered as meeting the requirements of rule 277 at crossings. These seven alternative methods were decided upon after a great deal of consideration and study had been given to modern supply line design, operation, and maintenance. Other equivalent methods are not prohibited.

SEC. 28. MISCELLANEOUS REQUIREMENTS

280. Supporting Structures for Overhead Lines.

A. Poles and Towers.

1. RUBBISH.

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

2. GUARDING POLES.

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

3. WARNING SIGNS.

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

Signs warning against trespass and calling attention to hazard are available in durable form to meet most ordinary requirements where metal poles or towers are concerned.

On wood poles stenciled signs are preferable as metal signs are a hazard to linemen. Small individual letters or figures of thin aluminum may be harmless.

5. POLE STEPS.

All overhead supply circuits should be inaccessible to unauthorized persons, at least as far as it is possible to make them so. The best method for so isolating supply wires is that of making the climbing of the supporting structures difficult without the use of special means, such as ladders, spurs, or removable steps. Metal steps should not be installed nearer than 6.5 feet to the ground. The use of steps only on the portion of the structure out of reach of the ground is very desirable in some locations. Some metallic structures require steps in order that they may be easily climbed by authorized persons.

6. IDENTIFICATION OF POLES.

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

7. OBSTRUCTIONS.

Obstructions, such as nails, bolts, tacks, or other metal pieces, may keep the lineman's spur from taking hold, thus causing the lineman to fall. Mail boxes, street signs, traffic-direction signs, etc., may constitute a serious hazard to workmen on poles.

C. Unusual Conductor Supports.

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

281. Tree Trimming.

The avoidance of contact of line conductors with trees is a difficult problem in many localities. Sometimes where large trees are present the poles are high enough to clear the trees without trimming, and sometimes considerable trimming is necessary. It is important to keep the wires clear by one method or another, to avoid grounds, short circuits, or crosses between circuits, as by two wires touching the same branch. Trees which shed their bark, such as the eucalyptus, or trees which are extremely brittle, such as the poplar, should be avoided, if at all possible, or trimmed below the level of the supply wires, if permission may be secured. The use of properly designed tools for this purpose is particularly important. Tools designed for the use of orchardists or gardeners are very rarely safe or suitable for use in this connection, for the reason that metallic connections often are present

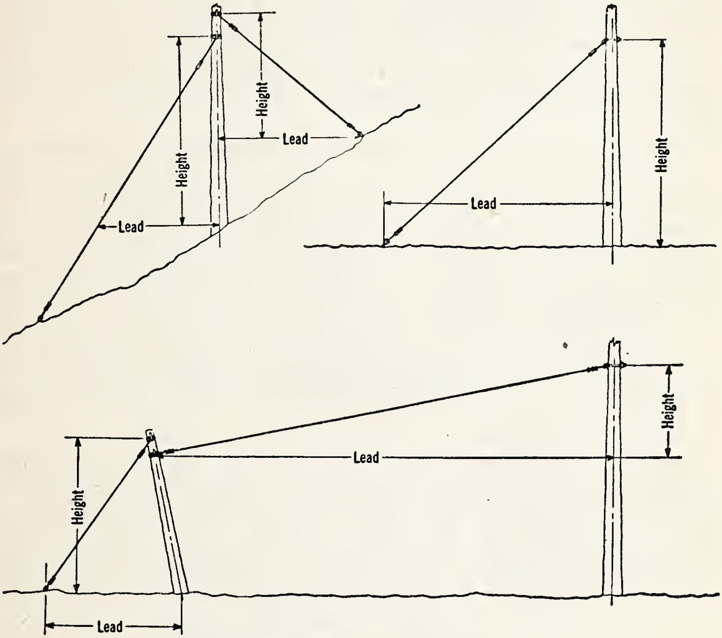


FIGURE 15.—*Lead and height of guys.*

between the cutting head and the operating handle. On this account they should be avoided, as workmen may be very seriously hurt or even killed by actual contact with high-voltage supply wires or by being thrown from a tall ladder or from the tree itself.

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

282. Guying.

A. Where Used.

If a pole does not have sufficient strength to support its load, the necessary strength should be provided by other means. This applies not only to definite strength requirements in these rules, but to poles for which no transverse-strength requirements are made. Storm guys for wood poles are accepted practice in most parts of the country. When it is necessary to give additional support to a pole by the use of a guy, the lead of the guy (see fig. 15) is an important factor in determining its required strength. Sometimes a head guy may be carried back to the next pole in line.

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

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

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

B. Strength.

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

D. Guy Fastenings.

A high-strength guy can, under stress, do considerable damage if wrapped around a soft wood pole unless a guy shim is used for protection. After the pole is once cut to any appreciable degree by a guy wire there is some likelihood of the pole snapping off at the cut under a heavy load.

Thimbles or their equivalent should be used on guys when attaching to anchor rods or guy bolts, as by so doing the load is distributed over a greater area.

E. Guy Guards.

A guy wire is hard to see not only at night but also by day in stormy weather, and if it is in the path of pedestrians it can cause serious accidents which in most cases would be avoided by covering the guy with a substantial and conspicuous wood or metal guard. Such a guard also helps to protect the guy from mechanical injury.

F. Insulating Guys from Metal Poles.

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

G. Anchor Rods.

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

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

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

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

H. Grounding.

See discussion of rule 283,B.

283. INSULATORS IN GUYS ATTACHED TO POLES AND TOWERS.

B. Use of Guy Insulators.

The chief reasons for placing strain insulators in or grounding guys may be briefly outlined as follows:

1. To protect pedestrians from guys which may be in accidental contact with supply wires.
2. To protect linemen working on poles from guys which may be in accidental contact with supply wires.
3. To minimize the possibility of plant damage which might result in unsafe conditions.

Also, guy wire insulators are sometimes used to keep grounded guys from supply-line working space where grounded guys would offer an additional hazard to linemen working in proximity to supply conductors.

In placing guys, every practicable effort should be made to avoid unnecessary crossings or situations involving proximity with power conductors. Where guy exposures cannot be avoided, present practices provide for appropriate clearances between guys and supply wires and for maintaining these clearances through adequate construction. Adequate climbing spaces and working spaces are also provided for linemen. These measures are of primary importance and grounding or the use of strain insulators is not a substitute for them.

It is not always possible through the use of insulators to prevent workmen or pedestrians from coming into contact with the exposed parts of guys. For example, in the case of a guy from a joint pole or a supply pole, the section of the guy near the pole may be energized by supply wires coming into contact with it regardless of how strain insulators are placed. If the contact is readily visible to a workman before the pole is climbed, however, the resulting hazard is not great. A similar situation from the standpoint of pedestrians may occur where the section of a guy near the ground is energized by broken supply wires.

Persons come in contact with guys only occasionally and incidentally and contacts between supply wires and guys occur infrequently where ample clearances and proper construction and maintenance have been provided. Consequently, the chance of injury to persons from exposed guys, even without insulators or special grounding, is relatively small in many cases. Where there is also reasonable assurance that the power wires involved will be promptly de-energized in the event of an accidental contact with a guy, the use of strain insulators or special grounding is usually unnecessary. The hazard involved is about as remote as the possibility of a charged wire falling directly on a pedestrian and it is, of course, impracticable to provide complete protection against such contingencies.

The use of guy insulators or the grounding of guys is most important in those cases where a part of a guy may accidentally come in contact with a supply wire and remain energized for some time at a point where it is not in easy view of the person who may touch the guy, or where guys may be jerked or oscillated into contact with supply wires. Where means for adequate grounding are available, grounding is often preferable to the use of strain insulators from both safety and cost standpoints.

284. Span-Wire Insulators.

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

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

285. Overhead Conductors.

A. Identification.

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

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

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

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

B. Branch Connections.

2. CLEARANCE.

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

286. EQUIPMENT ON POLES.

B. Location.

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

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

C. Guarding.

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

D. Hand Clearance.

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

E. Street-Lighting Equipment.

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

4. MATERIAL OF SUSPENSION.

It is not safe to use for the lowering equipment of lamps material which would deteriorate rapidly under ordinary bad weather conditions, or even from reasonable amounts of smoke, dust, etc. At locations where large amounts of deleterious gases or dust are present, as near chemical works, blast furnaces, cement mills, etc., special materials should be used, and they should be inspected much more frequently than in other locations. Nonmetallic ropes have for some time been used generally for the lowering equipment of certain types of street lamps. The deterioration of these ropes is not due so much to wear as to the action of the elements. Their strength may be reduced materially, due to decay of the interior fibers while they still appear to be sound. The necessity for systematic inspection is evident. The nonmetallic ropes are particularly susceptible to the effect of climatic changes and have a life which, in some localities, may be as short as two years. They, therefore, are a possible hazard, not only to passers-by but to workmen as well.

5. INSULATORS IN SUSPENSION ROPES.

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

6. ARC-LAMP DISCONNECTORS.

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

287. Protection for Exposed Overhead Communication Lines.

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

288. Circuits of One Class Used Exclusively in the Operation of Circuits of Another Class.

In the fourth edition of the code, this rule covered only communication circuits used exclusively in the operation of supply lines. Since developments in the art have made it necessary to supply power at points along communication systems, requirements have been included in the fifth edition for supply circuits used exclusively in the operation of communication circuits.

289. Overhead Electric Railway Construction.

A. Trolley-Contact Conductor Supports.

When a trolley pole slips from the contact wire, it not infrequently breaks the trolley wire loose from its supporting span or bracket suspension wire. It is desirable and reasonable to require that if the trolley wire becomes loosened from one hanger, or if one suspension span fails, no part of the trolley contact wire or its current-carrying parts come closer than 10 feet to any generally accessible place.

B. High-Voltage Contact Conductors.

As voltages become greater the danger rapidly increases, and it seems entirely reasonable to require that where voltages of more than 750 are used on overhead trolley-contact conductors in thickly settled communities the supports should be so frequent that even a break in the trolley conductor itself could not permit its falling to within reach of passers-by or so low as to obstruct traffic.

C. Third Rails.

Third rails have come into use on many interurban electric railways, but, on account of the difficulty of providing adequate protection, are seldom installed in locations which are open to the public. However, where they are so located the necessity for some kind of protection is very evident. This protection is best obtained by the installation of a continuous insulating strip or strips placed above the rail. The construction is, perhaps, the simplest and safest when the underrunning type of rail is employed, as the possibility of accidental contact is greatly reduced, and the operation of the railway under severe weather conditions is considerably improved. It is impossible to prevent contact with live parts under all circumstances, and on this account the warning to the public by suitable signs is recommended, and also the elimination of third rails except on private rights of way, elevated, or underground structures.

D. Prevention of Loss of Contact at Railroad Crossings.

Because of the greater clearance required for trolley-contact conductors at railroad crossings, the trolley pole at such places takes a nearly vertical position. The trolley springs are so adjusted that they are not in tension when the pole is in the vertical position. Thus, the greater the elevation of the contact conductor the less effective is the trolley-pole spring and, therefore, the less the pressure of the trolley wheel against the conductor. Because of this reduced pressure the jar of the car passing over the crossing can easily cause the wheel to slip from the trolley wire. By placing an inverted trough above the trolley wire so arranged as to catch the wheel should it leave the wire the car will be assured of power and thus will not be obliged to stop on the crossing. Another expedient sometimes adopted has been that of maintaining the trolley conductor in the spans immediately adjacent to the crossing span at the same elevation as the crossing, thereby reducing the effect of a sudden change in level. Even in this case, however, the trough is recommended.

Such special construction is not necessary where pantograph trolley with rollers or shoes is employed.

E. Guards Under Bridges.

The foregoing recommendations cover also the protection of the trolley conductor where the electric railway passes beneath a metallic bridge, except that here the guard must be of insulating material. The accidental short circuit produced between the trolley wire and the bridge should the trolley pole leave the wire would probably burn the wire down.

SEC. 29. RULES FOR UNDERGROUND LINES

290. Location.

A. General Location.

The municipality will usually prescribe the general location of an underground installation, and existing piping will be a determining factor. If given some freedom, a utility can eliminate much trouble and expense by a careful study of the existing underground structures, together with those being planned for the future. This may permit of more liberal manhole dimensions than are frequently provided in congested districts.

B. Ducts.

Ducts should be installed in straight lines, but may, where necessity arises, be installed with curves, in which case the radius of curvature should be as great as possible. If curves of short radius are used, cable, when being drawn through the duct, may drag hard around such a curve, and the lead sheath may be damaged either by scraping against the duct or by stretching.

291. Construction of Duct and Cable Systems.

A. Material, Size, and Finish of Ducts.

There are a number of different duct materials, among which may be named vitrified clay, "stone", or concrete, fiber, and wood. The first mentioned is used more generally for communication work, as it adapts itself most readily to construction, especially in multiple arrangement, and on account of its smooth finish and fireproof qualities. Fiber offers some advantages, as it is readily laid and is not liable to breakage as is clay duct. It is important that the interior of all ducts be smooth and free from projections, so that cable may be readily installed and removed without damage to the sheath. In order to prevent as far as possible trouble in one duct due to a burnt-out supply cable communicating to cables in adjacent ducts, single ducts offer some advantage, as the joints may be staggered and, in addition, a double wall is provided between cables.

B. Grading of Ducts.

It is important that ducts be so graded that all moisture can drain toward the manhole.

C. Settling.

When ducts are laid carelessly, shoulders frequently occur between adjoining sections of the ducts, which may damage the cable sheath and even render it impossible to pull the cable into the duct.

Ducts should be so designed that proper alinement can be maintained during construction. In clay conduit, holes are usually formed in the ends of each section of conduit and dowel pins are used to keep the alinement, while in fiber ducts the alinement can be obtained by use of sleeve, drive, or screw joints.

Where soil is soft and unstable, suitable foundations should be laid for conduits to rest upon. These may be of plank, concrete, or other materials, while in solid ground a suitable foundation may be provided by tamping the natural soil securely into place. When making excavations in a street, workmen frequently break into a conduit. Aside from the property damage, accidents occur from injuring the cables and their sheathing. It is sometimes advisable to provide covers to reduce this trouble. Good modern practice provides such protection at locations where it is needed. Where ducts are embedded in concrete, it is generally at least 3 inches thick.

D. Clearances.

Conduits should be located as far as practicable from other underground structures and especially from water mains and gas mains. Water from a broken main might undermine the conduit system, causing it to settle or even break. Gas leaking from its pipe will often find its way through considerable earth to a manhole. Thus, the greater the distance between such systems the less are the chances of damage.

E. Separations Between Supply and Communication Duct Systems.

To arrest the action of an electric-power arc and to prevent it from affecting communication cables, a barrier wall of concrete not less than 3 inches thick should be placed between ducts carrying supply conductors and adjacent ducts carrying communication conductors. This same means of limiting damage by cable arcs is often advisable for use between conduits containing large supply feeders used for different classes of service or acting as important tie lines between different stations.

On the account of the great cost of underground construction it is considered proper to allow the extension of communication and supply cables in existing jointly used duct lines which are not installed with sufficient separation as provided in this rule, if the proper precautions are taken in the manholes as given in par. 2 (Entering Manholes) of this rule.

When a supply cable fails, the arc caused may communicate the trouble to other cables in the same manhole. If communication cables and supply cables were close together, trouble originating in the supply cable might be transmitted to the communication cable. When it is necessary for both classes of lines to use the same manhole, they should naturally be separated as far as possible.

H. Duct Arrangement for Dissipation of Heat.

In a duct system the ducts in the center will dissipate heat less effectively than those on the sides or corners. In locating cable positions those of heaviest capacity should be placed in the corner positions and those of lowest capacity in the center. Ducts if grouped in large numbers cannot be relied upon to dissipate the heat properly, hence the number of supply ducts in a bank should be limited.

292. Construction of Manholes.

A. Minimum Strength.

It is not contemplated that every manhole should sustain the heaviest loads. They should provide strength in accordance with the conditions it is reasonable to presume will be met. During the process of installation many utilities require that suitable eyes or hooks be embodied in the concrete or brick walls of manholes, so located with respect to the duct-line entrance as to facilitate the installation and removal of cables.

B. Dimensions.

It is believed that the dimensions indicated can usually be provided in manholes and are the minima to provide a reasonably safe working space and also to give a workman a fair chance to get out in case of accident. The inside dimensions are especially important where transformers are to be installed in manholes. Sufficient space should be provided to safely and readily operate the cut-outs which are necessary with transformers.

C. Drainage.

The apparatus and cables in manholes are not accessible when covered with water. Where water is present, sediment is deposited on the apparatus and walls of the manhole which makes much cleaning necessary before work can be done in the manholes. Thus, it can be seen that well-drained manholes are desirable. Where drains lead directly into sewers, traps should be so installed that sewer gas cannot enter the manholes. Sewer gas may be dangerous because of its toxic effect or because of the lack of sufficient oyxgen content. Its presence is, however, generally evidenced by the sulphide of hydrogen caused by the decomposition of organic matter in the sewers. A poisonous effect is produced by the presence of carbon monoxide, and sulphides of ammonia and hydrogen. Carbon monoxide, gasoline vapor, and methane, combined with air, may produce an explosive mixture. All of these characteristics combine to make sewer gas extremely objectionable in manholes.

D. Ventilation.

Illuminating gas from nearby defective gas mains may find its way into a manhole. Illuminating gas may be poisonous and highly explosive and therefore very undesirable to have in manholes even in small quantities. Arcs occurring in manholes filled with gas have caused explosions which have not only damaged streets but nearby property and have injured persons in the vicinity.

E. Manhole Openings.

Ordinarily a manhole entrance 24 inches in diameter will provide sufficient space for ready exit.

H. Manhole Location.

The usual type of collapsible rail guard made of pipe or angle iron is considered as a suitable guard for manholes when the cover is removed. It is also desirable, as an extra precaution, to attach a red flag or warning sign or both to the guard. When manholes are located near track rails and guard rails cannot be used, the hole should be covered with a grating of iron bars as a protective measure. During rainy weather a manhole tent will serve as an effective guard or warning sign, and, in addition, keep the manhole free from rain. It is generally preferable that a workman be stationed above ground, if possible, but in many locations this will not be necessary.

293. Location of Cables.

A. Accessibility.

On account of the limited amount of space in manholes, cables should be carefully racked and so spaced and located that they are readily accessible at all times to the workman. When cables are crowded together with insufficient working space about them, the work performed upon them will be inferior to that performed on cables which are readily accessible.

The splicing of supply cables is a very important and particular operation. Joints probably give more trouble than any other part of an underground system, due to failure of insulation, overheating on account of poor contacts, and to entrance of moisture through poorly wiped joints in the lead sheath. They also require inspection from time to time to determine if they are heating excessively or if other defects are beginning to show. Thus, the importance of locating joints in readily accessible places and not in ducts between manholes is evident.

C. Separation Between Conductors.

In order to reduce the possibility of damage to low-tension cables by arcs in case of failure of high-tension cables, the two should be separated as far as practicable.

Where practicable in underground construction, supply and communication lines should, as with overhead construction, be given separate routes. In overhead lines a conflict or joint use of poles, where a separate route is impracticable, causes some additional hazard which is met to a reasonable degree by compliance with the required grade of construction.

In underground construction, as with overhead construction, consideration of expense in providing separate routes for supply and communication lines, or lack of room in a street where both utilities were installed, has sometimes necessitated the use of a single conduit line for both utilities. With a single conduit line, a somewhat greater hazard undoubtedly exists than with separate conduit lines but less hazard than with overhead construction in general, since hazard is mainly confined to employees, and the public is rarely endangered by underground lines. Where the supply lines are of high voltage or of very large capacity it is still more desirable to keep the two kinds of systems separate.

When, however, both systems are installed in a single conduit line, the requirements of the rule are considered, in general, to provide a reasonable degree of safety for workmen and the public.

It does not seem reasonable to require that cable extensions in jointly owned or occupied duct systems be separated but they may be continued as in the original installation.

As has been stated before, it is desirable to have supply and communication cables occupy opposite sides of the manhole.

296. Guarding of Live Parts in Manholes.

Where metal sheathing is used on cables it should be made continuous electrically and mechanically with the cases of equipment, such as switches and transformers.

Where metal sheathing is not used, the conductors should enter cases of equipment through openings which have proper bushing or gaskets to insure watertight joints.

Underground current-carrying parts exposed to contact in manholes and handholes are a source of great hazard and should not be allowed to exist. Live parts of transformers, switches, fuses, lightning arresters, or other apparatus should be enclosed completely as a protective measure.

297. Construction at Risers From Underground.

By using ordinary taped joints where conductors from lead-sheathed cable connect to open conductors of overhead systems a weak point is made in the system. By use of suitable potheads the insulation is protected from injury by electrostatic discharges or by moisture. By such construction the conductors are separated properly from each other and from the grounded metal sheath and are sufficiently insulated; also good electrical contacts are made, and the whole structure is rigid.

298. Identification of Conductors.

For the safety of workmen it is very important to have all cables plainly identified in every manhole. Identification may be made by use of metal tags, stenciling of the cable, or by charts showing the position of the cables. When tags are employed for this purpose, a noncorrodible material should be used and the marks should be such that they are not easily obliterated. As an additional precaution it is important that a uniform method for installing the cables in the ducts be followed throughout, or at least as far as possible. For instance, it is customary to install the local power-distribution cables in the top ducts of a duct line, not only, however, to facilitate their identification but also to permit the installation of an intermediate service hole, which requires access to these cables only, between manholes.

299. Identification of Apparatus Connected in Multiple.

The importance of indicating the multiple connection (network) of the apparatus covered by the rule is emphasized by the fact that, due to low-voltage feedback, the resulting excitation of the high-voltage side of individual transformers, regulators, or similar apparatus may be hazardous, even though such apparatus is disconnected from the high-voltage supply.

APPENDICES

CONTENTS

FIGURES

TABLES

*Figures 16, 18, 19, and 20 are reproduced separately as National Bureau of Standards Miscellaneous Publication M176 in a size large enough to permit accurate and rapid determination of values.

TABLES—continued

APPENDIX 1. CONDUCTOR DATA.

This Appendix contains the following:

1A. Tables of conductor sizes, strengths, and loadings.

Tables D1 to D10, inclusive, give the diameter, cross-sectional area, and breaking strength of most of the commonly used sizes of ACSR, copper, copper-covered, steel, and composite, conductors. The tables also include the transverse and vertical loadings and "conductor loading" per foot for these various conductors. These loading values are calculated in accordance with rule 251.

1B. Nomograph for conductor loading.

This device (fig. 16) provides a sufficiently precise graphic method of determining "conductor loading" values, except for certain conductors when used in the light-loading district. In determining permissible sags and tensions, however, such variations as may be found between the values obtained by this chart and values computed in accordance with rule 251 are of little importance, since one of the unloaded tension limits of rule 261,F,4 will control, except for unusually long spans.

1C. Physical constants of conductors.

The initial and final moduli of elasticity and the temperature coefficients of linear expansion for several commonly used sizes and materials of conductors are provided for reference in table D11.

1D. "Small" conductors and minimum supply conductor sizes at railroad crossings.

Conductors having certain dimensional characteristics are classified for clearance determinations as "small" conductors. Many such conductors now in general use are listed in table D12.

Also listed in this table are the certain sizes of conductors which are the smallest permitted by the code rules for supply lines at railroad crossings.

1E. Ruling spans.

The ruling span factor in the design of overhead lines is discussed and illustrative material (fig. 17) is provided.

TABLE D1.—*Conductor sizes, strengths, and loadings—Aluminum Cable Steel Reinforced*

Conductor size	Stranding	Over-all diameter	Cross-sectional area	Ultimate strength[1]	Linear loading of conductor: Light loading: Vertical (weight of conductor without ice)	Light loading: Transverse (9-lb wind per sq ft on conductor without ice)	Light loading: Conductor loading[2]	Medium loading: Vertical (conductor plus ¼ in. of radial ice)	Medium loading: Transverse (4-lb wind per sq ft on ice-covered conductor)	Medium loading: Conductor loading[2]	Heavy loading: Vertical (conductor plus ½ in. of radial ice)	Heavy loading: Transverse (4-lb wind per sq ft on ice-covered conductor)	Heavy loading: Conductor loading[2]
Cir. mils or AWG		*in.*	*sq in.*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
1,590,000	54A/19St	1.545	1.4070	56,000	2.045	1.159	2.401	2.603	0.6817	2.911	3.317	0.8483	3.734
1,510,000	54A/19St	1.506	1.3366	53,200	1.943	1.130	2.298	2.489	.6687	2.797	3.191	.8353	3.609
1,431,000	54A/19St	1.465	1.2663	50,400	1.840	1.099	2.193	2.373	.6550	2.682	3.062	.8217	3.480
1,351,500	54A/19St	1.424	1.959	47,600	1.738	1.068	2.091	2.259	.6413	2.568	2.935	.8080	3.354
1,272,000	54A/19St	1.382	1.1256	44,800	1.636	1.037	1.987	2.144	.6273	2.454	2.807	.7940	3.227
1,192,500	54A/19St	1.338	1.0552	43,100	1.534	1.006	1.884	2.028	.6127	2.339	2.677	.7793	3.098
1,113,000	54A/19St	1.293	.9849	40,200	1.429	.970	1.777	1.909	.5977	2.220	2.544	.7643	2.966
1,033,500	54A/7St	1.246	.9169	37,100	1.330	.935	1.676	1.795	.5820	2.107	2.416	.7487	2.839
954,000	54A/7St	1.196	.8464	34,200	1.227	.897	1.570	1.677	.5653	1.990	2.282	.7320	2.707
900,000	54A/7St	1.162	.7985	32,300	1.158	.8715	1.499	1.597	.5540	1.910	2.192	.7207	2.617
874,500	54A/7St	1.146	.7759	31,400	1.125	.8595	.1466	1.559	.5487	1.873	2.149	.7153	2.575
795,000	30A/19St	1.140	.7668	38,400	1.237	.8550	1.554	1.669	.5467	1.976	2.257	.7133	2.677
	26A/7St	1.108	.7261	31,200	1.098	.8310	1.427	1.520	.3560	1.832	2.098	.7027	2.523
	54A/7St	1.093	.7053	28,500	1.026	.8198	1.363	1.444	.5310	1.759	2.017	.6977	2.444
715,500	30A/19St	1.081	.6901	34,600	1.111	.8108	1.425	1.525	.5270	1.833	2.094	.6937	2.516
	26A/7St	1.051	.6535	28,100	.987	.7883	1.313	1.392	.5170	1.705	1.952	.6837	2.378
	54A/7St	1.036	.6348	26,300	.922	.7770	1.256	1.322	.5120	1.638	1.877	.6787	2.306
666,600	54A/7St	1.000	.5914	24,500	.858	.7500	1.190	1.247	.5000	1.564	1.791	.6667	2.221

636,000	30A/13St	1.019	.6134	31,500	.986	.7643	1.297	1.381	.5063	1.691	1.931	.6730	2.355
	26A/7St	.990	.5809	25,000	.874	.7425	1.197	1.262	.4967	1.576	1.801	.6633	2.229
	54A/7St	.977	.5643	23,600	.818	.7328	1.148	1.199	.4923	1.516	1.737	.6590	2.168
605,000	30A/19St	.994	.5835	30,000	.938	.7455	1.248	1.325	.4980	1.635	1.867	.6647	2.292
	26A/7St	.966	.5526	24,100	.832	.7275	1.155	1.211	.4900	1.526	1.746	.6567	2.175
	54A/7St	.953	.5368	22,500	.779	.7148	1.107	1.153	.4843	1.471	1.683	.6510	2.115
556,500	30A/7St	.953	.5391	27,200	.870	.7148	1.176	1.244	.4843	1.555	1.774	.6510	2.200
	28A/7St	.927	.5083	22,400	.765	.6953	1.084	1.131	.4757	1.447	1.653	.6423	2.083
500,000	30A/7St	.904	.4843	24,400	.7819	.6780	1.085	1.140	.4680	1.452	1.654	.6347	2.082
477,000	30A/7St	.883	.4620	23,300	.7459	.6623	1.0475	1.098	.4610	1.411	1.606	.6277	2.034
	30A/7St	.858	.4356	19,430	.6557	.6435	.9685	1.000	.4527	1.318	1.500	.6193	1.933
397,500	30A/7St	.806	.3850	19,980	.6216	.6045	.9171	.9500	.4353	1.2650	1.434	.6020	1.865
	26A7/St	.783	.3630	16,190	.5464	.5873	.8522	.8677	.4277	1.1874	1.344	.5943	1.780
336,400	30A/7St	.741	.3259	17,040	.5261	.5558	.8153	.9343	.4137	1.1512	1.298	.5803	1.732
	26A/7St	.721	.3072	14,050	.4624	.5408	.7615	.7644	.4070	1.0860	1.222	.5737	1.660
300,000	30A/7St	.700	.2906	15,430	.4691	.5250	.7540	.7646	.4000	1.0829	1.216	.5667	1.652
	26A/7St	.680	.2740	12,650	.4110	.5100	.7050	.7002	.3933	1.0231	1.145	.5600	1.585
266,800	26A/7St	.642	.2436	11,250	.3656	.4815	.6546	.6430	.3807	.9673	1.076	.5473	1.517
	6A/7St	.633	.2367	9,645	.3413	.4748	.6347	.6159	.3777	.9425	1.046	.5443	1.489
4/0	6A/1St	.563	.1939	8,420	.2921	.4223	.5634	.5449	.3543	.8700	.9533	.5210	1.396
3/0	6A/1St	.502	.1538	6,675	.2316	.3765	.4920	.4655	.3340	.7929	.8548	.5007	1.301
2/0	6A/1St	.447	.1219	5,345	.1837	.3353	.4323	.4005	.3157	.7300	.7727	.4823	1.221
1/0	6A/1St	.398	.0967	4,280	.1456	.2985	.3821	.3471	.2993	.6783	.7042	.4660	1.154
1	6A/1St	.355	.0767	3,480	.1155	.2663	.3403	.3037	.2850	.6365	.6473	.4517	1.099
2	7A/1St	.325	.0653	3,525	.1072	.2438	.3163	.2860	.2750	.6168	.6204	.4417	1.072
	6A/1St	.316	.0608	2,790	.0916	.2370	.3041	.2676	.2720	.6016	.5992	.4387	1.053
3	6A/1St	.281	.0482	2,250	.0727	.2108	.2730	.2378	.2603	.5726	.5585	.4270	1.013-
4	7A/1St	.257	.0411	2,288	.0674	.1928	.2542	.2251	.2523	.5581	.5382	.4190	.9921
	6A/1St	.250	.0383	1,830	.0576	.1875	.2461	.2131	.2500	.5485	.5241	.4167	.9796
5	6A/1St	.223	.0303	1,460	.0457	.1673	.2234	.1928	.2410	.5286	.4954	.4077	.9516
6	6A/1St	.198	.0240	1,170	.0362	.1485	.2029	.1755	.2327	.5115	.4704	.3993	.9270

See footnotes at end of table.

TABLE D1.—*Conductor sizes, strengths, and loadings—Aluminum Cable Steel Reinforced*—Continued

HIGH-STRENGTH LOW-CAPACITY CONDUCTORS [3]

Conductor size	Stranding	Over-all diameter	Cross-sectional area	Ultimate strength[1]	Linear loading of conductor								
					Light loading			Medium loading			Heavy loading		
					Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice)	Conductor loading[2]	Vertical (conductor plus ¼ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading[2]	Vertical (conductor plus ½ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading[2]
Cir. mils or AWG		*in.*	*sq in.*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
203, 000	8A/7St	0. 584	0. 2025	11, 140	0. 3356	0. 4380	0. 6018	0. 5950	0. 3613	0. 9161	1. 010	0. 5280	1. 444
203, 200	16A/19St	. 714	. 3020	27, 500	. 6749	. 5355	. 9115	. 9747	. 4047	1. 275	1. 430	. 5713	1. 850
211, 300	12A/7St	. 663	. 2628	19, 640	. 5263	. 4973	. 7741	. 8099	. 3877	1. 118	1. 250	. 5543	1. 677
190, 800	12A/7St	. 631	. 2373	17, 730	. 4752	. 4733	. 7207	. 7492	. 3770	1. 058	1. 179	. 5437	1. 608
176, 900	12A/7St	. 607	. 2200	16, 440	. 4406	. 4553	. 6836	. 7071	. 3690	1. 018	1. 129	. 5357	1. 560
159, 000	12A/7St	. 576	. 1977	15, 200	. 3960	. 4320	. 6360	. 6529	. 3587	. 9650	1. 065	. 5253	1. 498
134, 600	12A/7St	. 530	. 1674	12, 920	. 3352	. 3975	. 5700	. 5778	. 3433	. 8921	. 9759	. 5100	1. 411
110, 800	12A/7St	. 481	. 1378	10, 730	. 2760	. 3608	. 5043	. 5033	. 3270	. 8202	. 8862	. 4937	1. 324
101, 800	12A/7St	. 461	. 1266	9, 860	. 2536	. 3458	. 4788	. 4747	. 3203	. 7927	. 8513	. 4870	1. 291
80, 000	8A/1St	. 367	. 0847	5, 200	. 1498	. 2753	. 3634	. 3417	. 2890	. 6675	. 6891	. 4557	1. 136

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot, as specified in rule 251, NESC, 5th ed.
[3] The following standard types of ACSR conductors have high mechanical strength and relatively low current-carrying capacity. They are used mostly for overhead ground wires or for any use where mechanical strength is of primary importance.

TABLE D2.—*Conductor sizes, strengths, and loadings—copper cable—bare*

Conductor size	Stranding	Overall diameter	Cross-sectional area	Ultimate strength [1]			Linear loading of conductor								
							Light loading			Medium loading			Heavy loading		
				Hard-drawn (min)	Medium-hard drawn (min)	Annealed (max)	Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice)	Conductor loading [2]	Vertical (conductor plus ¼ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]	Vertical (conductor plus ½ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]
Cir. mils or AWG		*in.*	*sq in.*	*lb*	*lb*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
1,000,000	61	1.152	0.7854	45,030	35,100	29,060	3.088	0.8640	3.2566	3.5240	0.5504	3.7567	4.1156	0.7173	4.4676
	37	1.151	.7854	43,830	34,350	29,060	3.088	.8633	3.2564	3.5237	.5504	3.7564	4.1149	.7170	4.4669
750,000	61	.998	.5890	34.090	26,510	21,790	2.316	.7485	2.4840	2.7041	.4993	2.9398	3.2478	.6660	3.6054
	37	.997	.5890	33.400	26,150	21,790	2.316	.7478	2.4837	2.7038	.4990	2.9395	3.2471	.6657	3.6046
500,000	37	.814	.3927	22,510	17,550	14,530	1.544	.6105	1.7103	1.8749	.4380	2.1154	2.3613	.6047	2.7275
	19	.811	.3927	21,950	17,320	14,530	1.544	.6083	1.7095	1.8740	.4370	2.1143	2.3594	.6037	2.7254
400,000	19	.726	.3142	17,560	13,850	11,620	1,235	.5445	1.3997	1.5385	.4087	1.7819	1.9976	.5753	2.3688
350,000	19	.679	.2749	15,590	12,200	10,170	1.081	.5093	1.2450	1.3699	.3930	1.6152	1.9143	.5597	2.1887
	12	.710	.2749	15.140	12,020	10,170	1.081	.5325	1.2550	1.3796	.4033	1.6274	1.9336	.5700	2.2102
300,000	19	.629	.2356	13,510	10,530	8,718	.9263	.4718	1.0895	1.1997	.3763	1.4473	1.6285	.5430	2.0066
	12	.657	.2356	13,170	10,390	8,718	.9263	.4928	1.0992	1.2084	.3857	1.4585	1.6460	.5523	2.0262
250,000	19	.574	.1964	11,360	8,836	7,265	.7719	.4305	.9338	1.02816	.3580	1.2787	1.4398	.5247	1.8224
	12	.600	.1964	11,130	8,717	7,265	.7719	.4500	.9435	1.03625	.3667	1.2892	1.4561	.5333	1.9407
4/0	12	.552	.1662	9,483	7,378	6,149	.6533	.4140	.8234	0.9027	.3507	1.1584	1.3076	.5173	1.6962
	7	.522	.1662	9,154	7,269	6,149	.6533	.3915	.8116	.8934	.3407	1.1462	1.2890	.5073	1.6752
3/0	12	.492	.1318	7,556	5,890	4,876	.5181	.3690	.6861	.7489	.3307	1.0087	1.1351	.4973	1.5293
	7	.464	.1318	7,366	5,812	4,876	.5181	.3480	.6741	.7402	.3213	0.9969	1.1177	.4880	1.5096

See footnotes at end of table.

TABLE D2.—*Conductor sizes, strengths, and loadings—copper cable—bare*—Continued

Conductor size	Stranding	Overall diameter	Cross-sectional area	Ultimate strength [1]			Linear loading of conductor								
							Light loading			Medium loading			Heavy loading		
				Hard-drawn (min)	Medium-hard drawn (min)	Annealed (max)	Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice)	Conductor loading [2]	Vertical (conductor plus ¼ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]	Vertical (conductor plus ½ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]
Cir. mils or AWG		*in.*	*sq in.*	*lb*	*lb.*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
2/0	7	.414	.1045	5,926	4,641	3,868	.4109	.3105	.5650	.6174	.3047	.8785	0.9794	.4713	1.3769
1/0	7	.368	.08289	4,752	3,703	3,066	.3257	.2760	.4769	.5179	.2893	.7832	.8656	.4560	1.2684
1	7	.328	.06573	3,804	2,958	2,432	.2584	.2460	.4068	.4382	.2760	.7079	.7734	.4427	1.1811
	3	.360	.06773	3,620	2,875	2,432	.2559	.2700	.4220	.4456	.2867	.7199	.7908	.4533	1.2015
2	7	.292	.05213	3,045	2,361	2,007	.2049	.2190	.3499	.3735	.2640	.6474	.6975	.4307	1.1098
	3	.320	.05213	2,913	2,299	1,929	.2029	.2400	.3643	.3802	.2733	.6582	.7129	.4400	1.1278
3	3	.285	.04134	2,359	1,835	1,529	.1609	.2138	.3176	.3273	.2617	.6091	.6492	.4283	1.0678
4	3	.254	.03278	1,879	1,465	1,213	.1276	.1905	.2793	.2843	.2513	.5694	.5966	.4180	1.0185
6	3	.201	.02062	1,205	933.9	--------	.08026	.1508	.2035	.2205	.2337	.5113	.5163	.4003	0.9433

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot as specified in rule 251, NESC, 5th ed.

Table D3.—*Conductor sizes, strengths, and loadings—copper wire, solid—bare*

Conductor size	Over-all diameter	Cross-sectional area	Ultimate strength [1]			Linear loading of conductor								
						Light loading			Medium loading			Heavy loading		
			Hard drawn (min)	Medium hard drawn (min)	Annealed (max)	Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice)	Conductor loading [2]	Vertical (conductor plus ¼ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]	Vertical (conductor plus ½ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]
AWG	*in.*	*sq in.*	*lb*	*lb*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
4/0	0.4600	0.1662	8,143	6,980	5,983	0.6405	0.3450	0.7775	0.8613	0.3200	1.1088	1.2376	0.4867	1.6199
3/0	.4096	.1318	6,722	5,667	4,745	.5079	.3072	.6436	.7130	.3032	.9648	1.0737	.4699	1.4620
2/0	.3648	.1045	5,519	4,599	3,763	.4028	.2736	.5869	.5940	.2883	.8503	.9407	.4549	1.3349
1/0	.3249	.08289	4,517	3,730	2,984	.3195	.2437	.4518	.4983	.2750	.7592	.8326	.4416	1.2325
1	.2893	.06573	3,688	3,024	2,432	.2533	.2170	.3835	.4210	.2631	.6865	.7441	.4298	1.1493
2	.2576	.05213	3,003	2,450	1,929	.2009	.1932	.3287	.3587	.2525	.6287	.6720	.4192	1.0820
3	.2294	.04134	2,439	1,984	1,530	.1593	.1721	.2845	.3083	.2431	.5826	.6128	.4098	1.0272
4	.2043	.03278	1,970	1,584	1,213	.1264	.1532	.2486	.2676	.2348	.5460	.5643	.4014	.9825
5	.1819	.02600	1,591	1,265	961.9	.1002	.1364	.2193	.2345	.2273	.5166	.5242	.3940	.9458
6	.1620	.02062	1,280	1,010	762.9	.07946	.1215	.1952	.2075	.2207	.4929	.4911	.3873	.9155
7	.1443	.01635	1,030	806.6	605.0	.06302	.1082	.1752	.1856	.2148	.4739	.4636	.3814	.8903
8	.1285	.01297	826.0	643.9	479.8	.04997	.09638	.1586	.1676	.2095	.4583	.4408	.3762	.8695
9	.1144	.01028	661.2	514.2	380.5	.03963	.08580	.1445	.1530	.2048	.4456	.4218	.3715	.8521
10	.1019	.008155	529.2	410.4	314.0	.03143	.07643	.1326	.1409	.2006	.4351	.4058	.3673	.8373
11	.09074	.006467	422.9	327.6	249.0	.02492	.06806	.1225	.1309	.1969	.4264	.3924	.3636	.8250
12	.08081	.005129	337.0	261.6	197.5	.01977	.06061	.1138	.1227	.1936	.4192	.3810	.3603	.8144

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot as specified in rule 251, NESC, 5th ed.

TABLE D4.—*Conductor sizes, strengths, and loadings—Copperweld-copper and Copperweld—bare*

Conductors 2A, 3A, 4A, 5A, 6A, 7A, and 8A are 3-wire strand consisting of 2 HD copper and 1 extra-high-strength 30% conductivity Copperweld wires.
Conductors 1/OF, 1F and 2F, are 7-wire strand consisting of 6 HD copper and 1 extra-high-strength 30% conductivity Copperweld wires.
Conductors 4C, 6C, and 8C are 3-wire strand consisting of 2 HD copper and 1 high-strength 40% conductivity Copperweld wires.
Conductor 9 ½D is a 3-wire strand consisting of 1 HD copper and 2 high-strength 40% conductivity Copperweld wires.
Conductors 3 No. 10, 3 No. 11, and 3 No. 12, are 3-wire strand consisting of 3 high-strength 40% conductivity Copperweld wires.

Conductor	Over-all diameter	Cross-sectional area	Ultimate strength [1]	Linear loading of conductor								
				Light loading			Medium loading			Heavy loading		
				Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice)	Conductor loading [2]	Vertical (conductor plus ¼ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]	Vertical (conductor plus ½ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]
	in.	*sq in.*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
2 A	0.366	0.06799	5,876	0.2568	0.2745	0.4258	0.4483	0.2887	0.7232	0.7953	0.4553	1.2065
3 A	.326	.05392	4,810	.2036	.2445	.3682	.3827	.2753	.6615	.7172	.4420	1.1325
4 A	.290	.04276	3,938	.1615	.2175	.3209	.3294	.2633	.6118	.6527	.4300	1.0716
5 A	.258	.03391	3,193	.1281	.1935	.2821	.2860	.2527	.5716	.5994	.4193	1.0216
6 A	.230	.02689	2,585	.1016	.1725	.2502	.2508	.2433	.5395	.5555	.4100	.9804
7 A	.223	.02516	2,754	.09366	.1673	.2417	.2407	.2410	.5306	.5432	.4077	.9692
8 A	.199	.01995	2,233	.07427	.1493	.2168	.2139	.2330	.5063	.5089	.3997	.9371
1/0 F	.388	.09207	6,536	.3541	.2910	.5083	.5524	.2960	.8167	.9062	.4627	1.3075
1 F	.346	.07303	5,266	.2809	.2595	.4324	.4662	.2820	.7349	.8069	.4487	1.2133
2 F	.308	.05792	4,233	.2228	.2310	.3709	.3963	.2693	.6691	.7252	.4360	1.1362
4 C	.284	.04098	3,231	.1548	.2130	.3133	.3208	.2613	.6038	.6423	.4280	1.0618
6 C	.225	.02577	2,143	.0973	.1688	.2448	.2450	.2417	.5342	.5481	.4083	.9735
8 C	.179	.01604	1,362	.06067	.1343	.1974	.1940	.2263	.4881	.4829	.3930	.9126
9½ D	.174	.01539	1,743	.05646	.1305	.1922	.1883	.2247	.4832	.4755	.3913	.9059
3 No. 10	.220	.02446	2,882	.08713	.1650	.2366	.2332	.2400	.5246	.5348	.4067	.9619
3 No. 11	.196	.01940	2,286	.06910	.1470	.2124	.2078	.2320	.5015	.5019	.3983	.9310
3 No. 12	.174	.01539	2,040	.05480	.1305	.1915	.1866	.2247	.4821	.4739	.3913	.9046

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot as specified in rule 251, NESC, 5th ed.

TABLE D5.—*Conductor sizes, strengths, and loadings—copper, stranded—triple braid, weatherproof*

Conductor size	Ultimate strength [1]			Linear loading of conductor								
				Light loading			Medium loading			Heavy loading		
	Hard-drawn (min)	Medium-hard drawn (min)	Annealed (max)	Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice)	Conductor loading [2]	Vertical (conductor plus ¼ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]	Vertical (conductor plus ½ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]
Cir mils or AWG	*lb*	*lb*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
1,000,000	41, 610	32, 630	30, 510	3. 670	1. 275	3. 935	4. 276	0. 733	4. 559	5. 038	0. 900	5. 429
750,000	31, 730	24, 840	22, 880	2. 822	1. 125	3. 088	3. 366	. 667	3. 652	4. 066	. 833	4. 460
500,000	21, 390	16, 450	15, 260	1. 894	. 938	2. 163	2. 361	. 583	2. 651	2. 983	. 750	3. 385
350,000	14, 380	11, 590	10, 680	1. 345	. 788	1. 609	1. 749	. 517	2. 053	2. 309	. 683	2. 718
250,000	10, 790	8, 394	7, 628	. 984	. 683	1. 248	1. 346	. 470	1. 646	1. 862	. 637	2. 278
4/0	8, 696	7, 105	6, 456	. 800	. 623	1. 064	1. 136	. 443	1. 440	1. 627	. 610	2. 048
3/0	6, 998	5, 521	5, 119	. 653	. 563	. 912	. 964	. 417	1. 270	1. 431	. 583	1. 855
2/0	5, 630	4, 409	4, 061	. 522	. 503	. 775	. 808	. 390	1. 117	1. 250	. 557	1. 678
1/0	4, 514	3, 518	3, 219	. 424	. 465	. 679	. 695	. 373	1. 009	1. 121	. 540	1. 554
1	3, 614	2, 810	2, 554	. 328	. 413	. 577	. 578	. 350	. 896	. 981	. 517	1. 419
2	2, 893	2, 243	2, 107	. 270	. 383	. 518	. 507	. 337	. 829	. 898	. 503	1. 339

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot as specified in rule 251, NESC, 5th ed.

TABLE D6.—*Conductor sizes, strengths, and loadings—copper, solid—triple braid, weatherproof*

Conductor size	Ultimate strength [1]			Linear loading of conductor								
				Light loading			Medium loading			Heavy loading		
	Hard-drawn (min)	Medium-hard drawn (min)	Annealed (max)	Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice)	Conductor loading [2]	Vertical (conductor plus ¼ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]	Vertical (conductor plus ½ in. of radial ice	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]
AWG	*lb*	*lb*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
4/0	7,740	6,630	6,280	0.767	0.578	1.010	1.084	0.423	1.384	1.557	0.590	1.975
3/0	6,390	5,380	4,980	.629	.533	.875	.927	.403	1.231	1.381	.570	1.804
2/0	5,240	4,370	3,950	.502	.473	.740	.776	.377	1.083	1.205	.543	1.632
1/0	4,290	3,540	3,130	.407	.428	.641	.662	.357	.972	1.072	.523	1.503
1	3,503	2,870	2,550	.316	.390	.552	.555	.340	.872	.950	.507	1.387
2	2,850	2,330	2,030	.260	.356	.492	.485	.325	.803	.866	.492	1.306
3	2,320	1,885	1,606	.199	.315	.423	.407	.307	.730	.771	.473	1.215
4	1,872	1,505	1,274	.164	.293	.386	.363	.297	.689	.717	.463	1.164
6	1,216	1,010	801	.112	.251	.325	.294	.278	.625	.631	.445	1.082
8	785	612	504	.075	.218	.281	.243	.263	.578	.566	.430	1.021
10	503	390	330	.053	.188	.245	.208	.250	.545	.519	.417	.976
12	402	249	207	.035	.158	.212	.178	.237	.516	.476	.403	.934

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot as specified in rule 251, NESC, 5th ed.

Table D7.—*Conductor sizes, strengths, and loadings, Amerductor—SCP and SCG*

[The following conductors are furnished in both the SCP and SCG types. Conductor sizes 2, 4, 6, 8, 8X, and 9X consist of 2 hard-drawn copper wires and 1 zinc-coated steel wire. Conductor sizes 10 and 12 consist of 1 hard-drawn copper wire and 2 zinc-coated steel wires. SCP conductors have zinc coating on steel wire only. SCG conductors have zinc coating on all 3 wires of strand]

Conductor	Over-all diameter	Cross-sectional area	Ultimate strength [1]	Linear loading of conductor: Light loading: Vertical (weight of conductor without ice)	Light loading: Transverse (9-lb wind per sq ft on conductor without ice)	Light loading: Conductor loading [2]	Medium loading: Vertical (conductor plus ¼ in. of radial ice)	Medium loading: Transverse (4-lb wind per sq ft on ice-covered conductor)	Medium loading: Conductor loading [2]	Heavy loading: Vertical (conductor plus ½ in. of radial ice)	Heavy loading: Transverse (4-lb wind per sq ft on ice-covered conductor)	Heavy loading: Conductor loading [2]
	in.	*sq in.*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
2	0.392	0.0781	6,378	0.291	0.294	0.464	0.491	0.297	0.764	0.845	0.464	1.254
4	.310	.0489	4,486	.182	.233	.346	.356	.270	.637	.685	.437	1.103
6	.248	.0312	3,060	.116	.186	.269	.271	.249	.558	.581	.416	1.005
8	.196	.0195	2,112	.073	.147	.214	.212	.232	.504	.506	.399	.934
8X	.216	.0234	2,700	.086	.162	.233	.231	.239	.522	.531	.405	.958
9X	.193	.0186	2,346	.069	.145	.211	.207	.231	.500	.500	.398	.929
10	.220	.0245	3,853	.088	.165	.237	.235	.240	.526	.535	.407	.962
12	.174	.0154	2,426	.055	.131	.192	.187	.225	.483	.474	.391	.904

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot as specified in rule 251, NESC, 5th ed.

TABLE D8.—*Conductor sizes, strengths, and loadings, galvanized steel conductors, solid and three-wire*

[The following conductors (sizes 4, 6, and 8, both solid and three-wire) are designated Crapo HTC by Indiana Steel & Wire Co. and Amersteel by American Steel & Wire Co. Conductors of sizes 9, 10, 12 and 14 are designated Crapo HTL by Indiana Steel & Wire Co. and Amertel by American Steel & Wire Co. These conductors are manufactured and sold by Indiana Steel & Wire Co. and American Steel & Wire Co. The data shown in the first four columns are reproduced by permission from data copyrighted in 1938, 1939, and 1940 by Indiana Steel & Wire Co., which has been granted certain fundamental patents.]

Conductor size and type	Stranding	Overall diameter	Cross-sectional area	Ultimate strength[1]	Linear loading of conductor								
					Light loading			Medium loading			Heavy Loading		
					Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice)	Conductor loading[2]	Vertical (conductor plus ¼ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading[2]	Vertical (conductor plus ½ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading[2]
BWG		in.	sq in.	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft
4 { 80	Solid	0.238	0.04449	3,559	0.154	0.179	0.286	0.306	0.246	0.583	0.613	0.413	1.029
4 { 130	do	.238	.04449	5,784	.154	.179	.286	.306	.246	.583	.613	.413	1.029
6 { 80	do	.203	.03237	2,589	.112	.152	.239	.252	.234	.534	.550	.401	.971
6 { 130	do	.203	.03237	4,208	.112	.152	.239	.252	.234	.534	.550	.401	.971
8 { 80	do	.165	.02138	1,711	.0735	.124	.194	.203	.222	.491	.488	.388	.913
8 { 130	do	.165	.02138	2,780	.0735	.124	.194	.203	.222	.491	.488	.388	.913
9 85	do	.148	.01720	1,462	.0595	.111	.176	.183	.216	.473	.463	.383	.891
10 85	do	.134	.01410	1,199	.0489	.101	.162	.168	.211	.460	.443	.378	.872
12 { 85	do	.109	.00933	793	.0322	.0818	.138	.144	.203	.439	.411	.370	.843
12 { 135	do	.109	.00933	1,213	.0322	.0818	.138	.144	.203	.439	.411	.370	.843
14 85	do	.083	.00541	460	.0188	.0623	.115	.122	.194	.419	.381	.361	.815
4 { 80	3-wire	.297	.04487	3,624	.156	.223	.322	.326	.266	.611	.652	.432	1.072
4 { 130	do	.297	.04487	5,610	.156	.223	.322	.326	.266	.611	.652	.432	1.072
6 { 80	do	.252	.03225	2,604	.112	.189	.270	.269	.251	.558	.579	.417	1.004
6 { 130	do	.252	.03225	4,295	.112	.189	.270	.269	.251	.558	.579	.417	1.004
8 { 80	do	.207	.02171	1,753	.075	.155	.222	.217	.236	.511	.515	.402	.943
8 { 130	do	.207	.02171	2,915	.075	.155	.222	.217	.236	.511	.515	.402	.943

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot as specified in rule 251, NESC, 5th ed.

TABLE D9.—*Conductor sizes, strengths, and loadings, galvanized steel conductors, three-wire*

[The following are 3-wire Bethanized conductors manufactured and sold by the Bethlehem Steel Co.]

Conductor size and type	Over-all diameter	Cross-sectional area	Ultimate strength [1]	Linear loading of conductor								
				Light loading			Medium loading			Heavy loading		
				Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice)	Conductor loading [2]	Vertical (conductor plus ¼ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]	Vertical (conductor plus ½ in. of radial ice)	Transverse (4-lb wind per sq ft on ice-covered conductor)	Conductor loading [2]
BWG	*in.*	*sq in.*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
4R3-A	0.297	0.04487	5,610	0.156	0.223	0.322	0.326	0.266	0.611	0.652	0.432	1.072
6R3-A	.252	.03225	4,296	.112	.189	.270	.269	.251	.558	.579	.417	1.004
8R3-A	.207	.02171	2,915	.075	.155	.222	.217	.236	.511	.515	.402	.943

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot as specified in rule 251, NESC, 5th ed.

TABLE D10.—*Conductor sizes, strengths, and loadings, galvanized steel strand*

Conductor size	Stranding	Overall diameter	Cross-sectional area	Ultimate strength [1]					Linear loading of conductor								
									Light loading			Medium loading			Heavy loading		
				Utilities grade	Common grade	Siemens-Martin grade	High-strength grade	Extra-high-strength grade	Vertical (weight of conductor without ice)	Transverse (9-lb wind per sq ft on conductor without ice	Conductor loading [2]	Vertical (conductor plus 1/4 in. of radial ice)	Transverse 4-lb wind per sq ft on ice covered conductor	Conductor loading [2]	Vertical (conductor plus 1/2 in. of radial ice)	Transverse (4-lb wind per sq ft on ice covered conductor	Conductor loading [2]
in.	*in.*	*in.*	*sq in.*	*lb*	*lb*	*lb*	*lb*	*lb*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*	*lb/ft*
1/8	7	0.123	0.00924	-------	540	910	1,330	1,830	0.0318	0.092	0.147	0.147	0.208	0.445	0.420	0.374	0.852
5/32	7	.156	.01487	-------	870	1,470	2,140	2,940	.0513	.117	.178	.178	.219	.472	.459	.385	.889
3/16	7	.186	.02113	-------	1,150	1,900	2,850	3,990	.0729	.140	.208	.208	.229	.499	.499	.395	.926
	7	.195	.02323	2,400	-------	-------	-------	-------	.0803	.146	.216	.218	.232	.508	.513	.398	.939
7/32	7	.216	.02850	-------	1,540	2,560	3,850	5,400	.0983	.162	.239	.244	.239	.532	.543	.405	.967
1/4	3	.259	.03393	3,150	-------	-------	-------	-------	.1167	.194	.277	.275	.253	.564	.589	.420	1.013
	3	.259	.03393	4,500	-------	-------	-------	-------	.1167	.194	.277	.275	.253	.564	.589	.420	1.013
	7	.240	.03519	-------	1,900	3,150	4,750	6,650	.1210	.180	.267	.274	.247	.559	.581	.413	1.003
9/32	7	.279	.04755	4,600	2,570	4,250	6,400	8,950	.1640	.209	.316	,328	.260	.609	.649	.426	1,066
5/16	3	.312	.04954	6,500	-------	-------	-------	-------	.1706	.234	.340	.346	.271	.629	.675	.437	1.094
	7	.312	.05946	-------	3,200	5,350	8,000	11,200	.2050	.234	.361	.380	.271	.657	.710	.437	1.124
	7	.327	.06532	6,000	-------	-------	-------	-------	.2250	.245	.383	.404	.276	.679	.740	.442	1.152
3/8	3	.356	.06415	8,500	-------	-------	-------	-------	.2203	.267	.396	.409	.285	.689	.752	.452	1.167
	7	.360	.07917	11,500	4,250	6,950	10,800	15,400	.2730	.270	.434	.463	.287	.735	.807	.453	1.215
7/16	7	.435	.1156	18,000	5,700	9,350	14,500	20,800	.3990	.326	.565	.612	.312	.877	.981	.478	1.381
1/2	7	.495	.1497	25,000	7,400	12,100	18,800	26,900	.5170	.371	.686	.748	.332	1.008	1.136	.498	1.530
	19	.500	.1492	-------	7,620	12,700	19,100	26,700	.5040	.375	.678	.738	.333	1.000	1.126	.500	1.522
9/16	7	.564	.1943	-------	9,600	15,700	24,500	35,000	.6710	.423	.843	.925	.355	1.181	1.332	.521	1.720
	19	.565	.1905	-------	9,640	16,100	24,100	33,700	.6370	.424	.815	.891	.355	1.149	1.300	.522	1.691
5/8	7	.621	.2356	-------	11,600	19,100	29,600	42,400	.813	.466	.987	1.084	.374	1.337	1.510	.540	1.894
	19	.625	.2332	-------	11,000	18,100	28,100	40,200	.796	.469	.974	1.068	.375	1.322	1.496	.542	1.881
3/4	19	.750	.3358	-------	16,000	26,200	40,800	58,300	1.155	.563	1.335	1.466	.417	1.714	1.932	.583	2.308

[1] The values in this column are called "breaking strength" by some wire manufacturers.
[2] The values in this column give the conductor loading per foot as specified in rule 251, NESC, 5th ed.

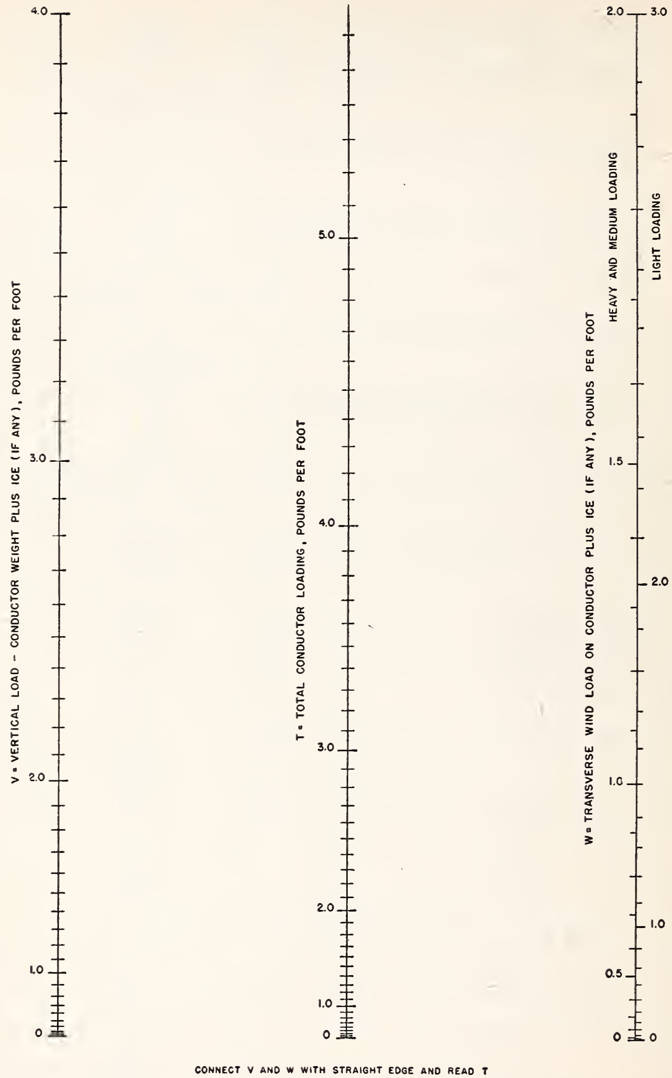
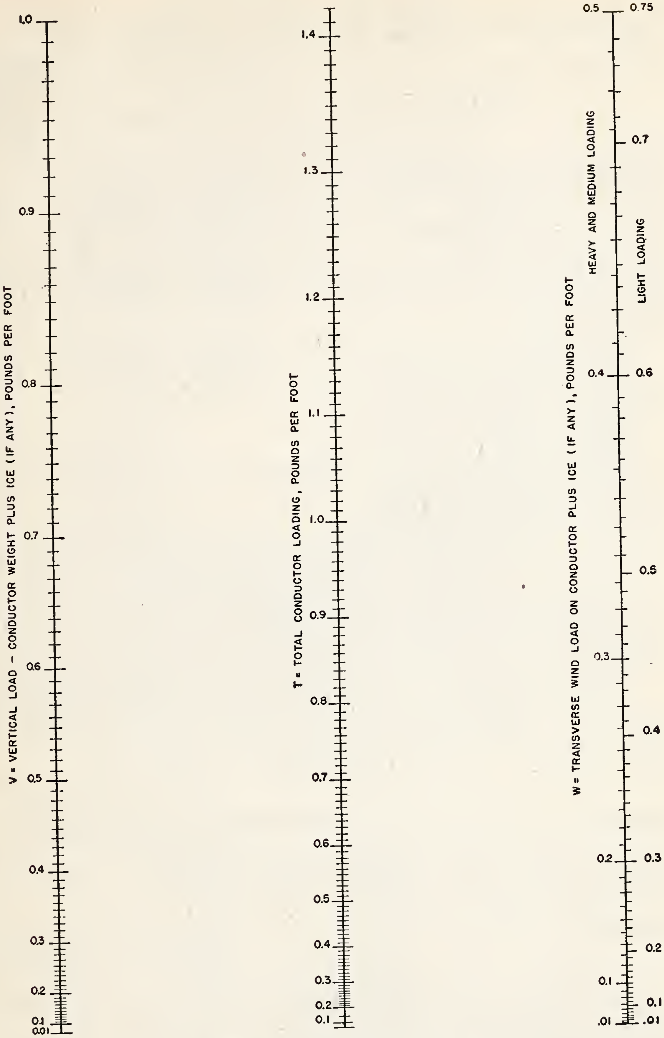


FIGURE 16.—*Conductor loading nomograph, vertical, transverse, and conductor loads—pounds per linear foot of conductor*

[See also comments on p. 309 regarding light loading.]



CONNECT V AND W WITH STRAIGHT EDGE AND READ T

FIGURE 16.—(Continued).

APPENDIX 1C. TABLE D11.—*Physical constants of conductors*

Conductor	Modulus of elasticity: Initial	Modulus of elasticity: Final	Temperature coefficient of linear expansion per degree Fahrenheit
	lb/in.^{2}	*lb/in.*^{2}	
Aluminum Cable Steel Reinforced:			
Nos. 4/0 to 6 (6/1)	10, 250, 000	11, 500, 000	0. 000 010 5
Nos. 4 and 2 (7/1)	11, 600, 000	12, 600, 000	. 000 010 1
Copper, solid, hard-drawn	14, 500, 000	17, 000, 000	. 000 009 4
Copper, stranded, hard-drawn:			
3- and 12-strand	14, 000, 000	17, 000, 000	. 000 009 4
7- and 19-strand	14, 500, 000	17, 000, 000	. 000 009 4
Copperweld, solid	22, 000, 000	24, 000, 000	. 000 007 2
Copperweld, stranded	20, 500, 000	23, 000, 000	. 000 007 2
Copperweld-copper:			
Nos. 2A to 6A	16, 500, 000	19, 000, 000	. 000 008 5
Nos. 7A and 8A	18, 500, 000	21, 000, 000	. 000 008 1
Nos. 6C and 8C	16, 500, 000	19, 000, 000	. 000 008 5
Nos. 8D and 9½D	19, 500, 000	22, 000, 000	. 000 007 8
Nos. 1/0F, 1F, and 2F	15, 500, 000	18, 000, 000	. 000 009 0
Steel-copper:			
Amerductor Nos. 2 to 6		19, 800, 000	. 000 008 2
Amerductor No. 8		20, 500, 000	. 000 008 2
Amerductor No. 8X		16, 700, 000	. 000 007 3
Amerductor No. 9X		17, 000, 000	. 000 007 3
Amerductor Nos. 10 and 12		21, 700, 000	. 000 007 3
Steel, solid—Crapo HTC and Amersteel		29, 000, 000	. 000 005 7
Steel, 3-wire—Crapo HTC and Amersteel		27, 000, 000	. 000 005 7

APPENDIX 1D. TABLE D12.—*"Small" conductors and minimum supply conductor sizes at railroad crossings*

[This table covers conductors included in tables D1 to D10 only. For other conductors check manufacturers' data against rules 232,A,2; 232,B,1(a); 233,A,2; 233,B,1(a); and 261,F,2, exception 1]

Conductor material	"Small" conductors	Minimum allowable sizes at railroad crossings
Aluminum Cable Steel Reinforced	4 AWG and smaller	6 AWG.
Copper, stranded	6 AWG 3-strand	6 AWG—HD. 4 AWG—MHD & Annealed.
Copper, solid	7 AWG and smaller	6 AWG—HD & MHD. 4 AWG—Annealed.
Copperweld-copper	5A, 6A, 7A, and 8A 6C and 8C [a] 9½D [a]	8A. 6C.
Copperweld	3 No. 10 3 No. 11 3 No. 12 [a]	3 No. 10.
Amerductor	6 and 8 8X and 9X 10 and 12 [a]	6. 8X.
Steel, 3-wire, galvanized:		
Amersteel and Crapo HTC	6 and 8 BWG	6 BWG.
Ruralductor	6R3-A and 8R3-A	6R3-A.
Steel, solid, galvanized:		
Amersteel and Crapo HTC	4 BWG and smaller	6 BWG.

[a] Each wire of these conductors is 0.09 inch or less in diameter. See notes to rules 232,A,2 and 233,A,2.

Appendix 1E.—Ruling Spans

In considering an overhead conductor span four dimensions are of particular importance. (See A of fig. 17.)

To establish these dimensions and to string the conductor so that clearance and allowable percentage of ultimate strength will conform to code requirements, it is necessary to know the sags and tensions at various temperatures, based on the assumed conductor loading. (See rule 251).

Because a permanent stretch or "set" is produced the first time a conductor is subjected to stress, sags and tensions are determined for two conditions, first, for new or unstretched

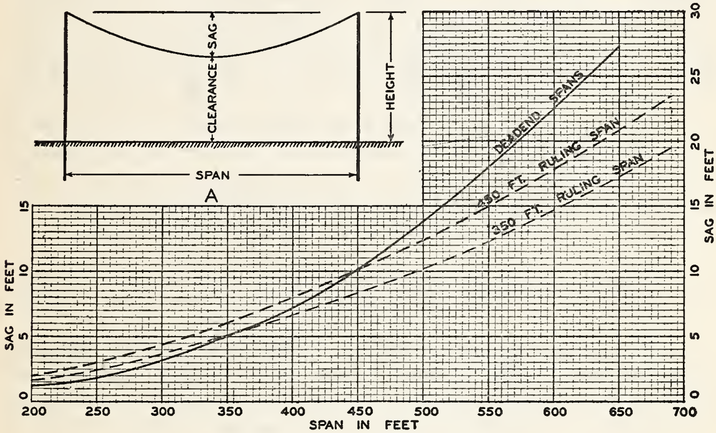


Figure 17.—*Ruling spans.*

conductors, designated as "initial," and second, for stretched conductors after maximum loading has been experienced, designated as "final" or "design" sags and tensions. Computations are made for a sufficient number of span lengths to secure smooth curves so that values for intermediate spans may be easily obtained.

The "final" curves are used as the basis for design, i. e., to establish the other dimensions in figure 17. They are also used as the basis for stringing conductors that are prestretched to produce the permanent "set" artificially during the sagging operation.

The "initial" curves are used as the basis for stringing new conductors so that after they have been subjected to the assumed maximum loading conditions the "final" or "design" sags and tensions will not be exceeded.

"Final" and "initial" sag-and-tension charts are ordinarily furnished by manufacturers. The basic assumptions of temperature, conductor loading, and tension are necessarily the same for all spans calculated but result in unloaded tensions which vary with span length.

In actual practice conductors are usually strung over a series of supports without intermediate dead ends and the stringing tension is necessarily the same in all spans regardless of length. For field use it is therefore necessary to prepare stringing sag curves or tables corresponding to a constant stringing tension for all spans. These sags are proportional to the squares of the span lengths and are not the same as shown on the charts described above. To prepare such curves or tables a ruling span is first determined and the tension in this ruling span, or sags based on this tension, are then used for stringing all spans between dead ends. A satisfactory rule is to make the ruling span approximately equal to the average span plus two-thirds of the difference between the maximum span and average span between dead ends:

Ruling span = average span + 2/3 (maximum span − average span).

Although the tension is substantially the same in all spans between dead ends at the time of stringing, subsequent changes in temperature and loading will tend to unbalance the tension in adjacent spans of unequal length. This is counteracted by the deflection of supports, hence the tensions in a line of unequal spans will agree closely with the tensions in the ruling span.

Figure 17 shows a typical sag curve obtained from computations for several spans as described above. For the purpose of illustration, only one curve is shown. Charts ordinarily furnished by manufacturers show sag curves at several temperatures and the corresponding tension curves.

The effect of ruling span on the sags is illustrated by the dotted curves. Assume that the ruling span has been determined to be 350 ft. The sag in the ruling span is 5 ft, and the dotted curve intersecting the sag curve at a 350-ft span shows the sags in other spans that will result from the use of this ruling span. Likewise the dotted curve intersecting the sag curve at a 450-ft span shows the sags when the ruling span is 450 ft. These dotted curves are obtained by calculating the sags as directly proportional to the squares of the span lengths:

$$\text{Sag} = \frac{\text{span}^2}{\text{ruling span}^2} \times \text{sag of ruling span.}$$

For spans isolated by dead ends at each end or for a series of spans between dead ends all of the same length or substantially so, the ruling span will be the same as the actual span and the sags may be taken directly from the sag-and-tension chart.

Figure 18 (Appendix 2C) shows a catenary curve which may be used for determining the percent of midspan sag for points between the center of the span and either support when both supports are at the same elevation.

APPENDIX 2. SAG DATA USED IN DETERMINING CLEARANCES.

This appendix contains the following:

2A. Maximum sag increases.

The data listed in table D13 are for use in determining the maximum additional clearance necessary to meet the requirements of rules 232,B,1 and 233,B,1.

Maximum sag increases of certain of the composite conductors in the medium- and light-loading districts have not been listed as they cannot be determined from available data.

The values for Amerductor and Amersteel are determined from curves and data copyrighted 1943 by the American Steel & Wire Co. and the Indiana Steel & Wire Co. Those for Crapo HTC conductors are copyrighted 1943 by the Indiana Steel & Wire Co. Other values were obtained through the courtesy of the Aluminum Company of America for Aluminum Cable Steel Reinforced, and the Copper Wire Engineering Association for copper-type conductors.

2B. Midspan sags.

The changes in sags at midspan from initial sags at three specified stringing temperatures to final unloaded sags at 60° F for some of the more commonly used conductors are given in tables D14 to D20, inclusive.

Tables D21 to D23, inclusive, give the total sags (and 120° F sags where these are greater) for a number of conductors used in long span construction. These data are given for various span lengths and for the three loading districts.

The values listed for the various wire materials have been obtained through the courtesy of the following organizations:

Aluminum Company of America for Aluminum Cable Steel Reinforced.

American Steel & Wire Company for Amerductor and Amersteel.

Copper Wire Engineering Association for copper-type conductors.

Indiana Steel & Wire Company for Crapo HTC galvanized steel conductors.

2C. Catenary curve.

This curve (fig. 18) gives the approximate values of the sag at all points in a span, expressed in percentage of the center sag. The error is negligible for all spans in which the center sag is less than 10 percent of the span length.

834055°—49——22

TABLE D13.—*Maximum sag increase (msi) of bare conductors for three loading districts*

[Loading and tension limitations conform to rules 251 and 261,F,4. Loaded tensions do not exceed 60 percent or, where indicated, 50 percent of the ultimate strength of the conductors]

Conductor size, type, and stranding	Maximum sag increase		
	Heavy	Medium	Light
ALUMINUM CABLE STEEL REINFORCED			
AWG	*ft*	*ft*	*ft*
4/0 (6/1)	6.8	8.4	[a] 6.6
3/0 (6/1)	6.8	8.2	[a] 6.8
2/0 (6/1)	6.4	8.0	[a] 7.1
1/0 (6/1)	6.3	8.0	[a] 7.2
1 (6/1)	6.2	8.2	[a] 7.0
2 (6/1)	4.9	6.8	[a] 7.0
2 (7/1)	6.0	8.4	[a] 9.0
4 (6/1)	4.4	6.5	[a] 7.0
4 (7/1)	5.3	8.0	[a] 8.2
6 (6/1)	3.5	5.6	[a] 6.3
STRANDED HARD-DRAWN COPPER			
Cir. mils			
500,000 (37)	[a] 3.0	[a] 3.0	[a] 3.0
500,000 (19)	[a] 3.1	[a] 3.1	[a] 3.1
450,000 (19)	[a] 3.1	[a] 3.1	[a] 3.1
400,000 (19)	[a] 3.1	[a] 3.1	[a] 3.1
350,000 (19)	[a] 3.1	[a] 3.1	[a] 3.1
350,000 (12)	[a] 2.9	[a] 2.9	[a] 2.9
300,000 (19)	3.1	[a] 3.1	[a] 3.1
300,000 (12)	3.1	[a] 3.1	[a] 3.1
250,000 (19)	3.0	[a] 3.0	[a] 3.0
250,000 (12)	3.1	[a] 3.1	[a] 3.1
AWG			
4/0 (19)	3.3	[a] 3.0	[a] 3.0
4/0 (12)	3.3	[a] 3.0	[a] 3.0
4/0 (7)	2.8	[a] 3.0	[a] 3.0
3/0 (12)	3.3	[a] 3.1	[a] 3.1
3/0 (7)	3.1	[a] 3.1	[a] 3.1
2/0 (7)	3.1	3.1	[a] 3.1
1/0 (7)	3.1	3.6	[a] 3.1
1 (7)	3.0	4.0	[a] 3.0
1 (3)	2.6	3.7	3.3
2 (7)	2.8	4.0	[a] 3.0
2 (3)	2.5	3.6	3.4
3 (3)	2.4	3.6	4.4
4 (3)	2.3	4.0	4.7
SOLID HARD-DRAWN COPPER			
AWG			
2	2.8	4.0	[a] 3.1
3	2.7	4.0	[a] 3.0
4	2.5	3.9	[a] 3.1
5	2.3	3.8	[a] 3.5
6	2.1	3.5	4.7
8	1.7	2.9	5.9

See footnotes at end of table.

TABLE D13.—*Maximum sag increase (msi) of bare conductors for three loading districts*—Continued

Conductor size, type, and stranding	Maximum sag increase		
	Heavy	Medium	Light
COPPERWELD-COPPER			
	ft.	*ft*	*ft*
2 A	7.2	9.6	4.5
3 A	7.0	9.8	5.0
4 A	6.8	9.9	8.0
5 A	6.4	9.6	11.7
6 A	5.9	9.2	13.4
7 A	6.8	10.6	16.2
8 A	6.3	10.0	16.6
6 C	3.0	6.6	9.8
8 C	2.2	5.3	9.9
8 D	9.9	15.3	24.2
9½ D	5.3	8.6	16.0
1/0 F	5.2	4.1	3.2
1 F	5.1	4.2	3.3
2 F	4.8	5.2	3.5
COPPERWELD			
AWG			
3 No. 12	7.2	14.0	26.6
STEEL-COPPER, THREE-WIRE AMERDUCTOR SCP OR SCG			
2	6.5	8.4	5.1
4	7.0	9.9	10.3
6	6.6	10.0	13.9
8	5.9	9.4	15.5
8X	10.0	15.2	23.6
9X	10.3	16.5	27.4
10	14.2	21.8	33.2
12	11.1	18.0	32.7
AMERSTEEL, THREE-WIRE, GALVANIZED			
BWG			
4 3S–130	10.1	14.4	17.8
6 3S–130	9.4	14.2	19.7
4 3S–80	4.0	5.8	7.1
6 3S–80	3.5	5.2	7.1

See footnotes at end of table.

TABLE D13.—*Maximum sag increase (msi) of bare conductors for three loading districts*—Continued

Conductor size, type, and stranding	Maximum sag increase		
	Heavy	Medium	Light
CRAPO, STRANDED, THREE-WIRE, GALVANIZED STEEL			
BWG	*ft*	*ft*	*ft*
4 HTC-130	10.1	14.4	17.8
6 HTC-130	9.4	14.2	19.7
8 HTC-130	7.2	11.3	(b)
4 HTC-80	4.0	5.8	7.1
6 HTC-80	3.5	5.2	7.1
8 HTC-80	(b)	4.1	(b)
AMERSTEEL, SOLID, GALVANIZED			
BWG			
4 S-130	[a] 6.6	[a] 10.0	[a] 10.1
6 S-130	[a] 5.5	[a] 8.5	[a] 12.2
4 S-80	[a] 1.4	[a] 2.3	[a] 3.0
6 S-80	[a] 1.8	[a] 2.8	[a] 4.3
CRAPO, SOLID, GALVANIZED			
BWG			
4 HTC-130	[a] 6.6	[a] 10.0	[a] 10.1
6 HTC-130	[a] 5.5	[a] 8.5	[a] 12.2
8 HTC-130	[a] 4.3	[a] 7.1	[a] 12.3
4 HTC-80	[a] 1.4	[a] 2.3	[a] 3.0
6 HTC-80	[a] 1.8	[a] 2.8	[a] 4.3
8 HTC-80	(b)	[a] 2.5	(b)

[a] Based on maximum tension of 50 percent of ultimate strength of conductors.
[b] Could not be determined from available data. See discussion of Rule 233, B.

TABLE D14.—*Changes in midspan sags of conductors (unloaded conditions) Aluminum Cable Steel Reinforced*

HEAVY-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent of the ultimate strength of the conductors.]

Conductor size and stranding	Initial temperature	Sag increase for various span lengths in feet								
		200 [1]	250	300	350	400	450	500	550	600
AWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2/0 (6/1)	32	0.7	1.1	1.3	1.9	2.5	3.1	3.7	4.4	4.7
	60	.4	.8	1.0	1.4	2.0	2.5	3.0	3.5	3.5
	90	.0	.2	.3	.7	1.2	1.5	2.0	2.4	2.2
1/0 (6/1)	32	.7	1.2	1.6	2.4	3.0	3.6	4.4	4.6	4.6
	60	.5	.9	1.3	1.9	2.5	3.0	3.6	3.4	3.2
	90	.0	.4	.7	1.2	1.6	2.1	2.0	1.9	1.8
1 (6/1)	32	.8	1.2	1.9	2.5	3.0	3.5	3.8	3.6	3.3
	60	.6	1.0	1.6	2.1	2.5	2.6	2.7	2.5	2.2
	90	.3	.7	1.1	1.5	1.7	1.5	1.4	1.1	1.0
2 (6/1)	32	.8	1.4	2.2	3.0	3.5	3.4	3.0	2.7	2.4
	60	.6	1.1	1.8	2.5	2.5	2.3	2.0	1.7	1.4
	90	.3	.7	1.3	1.6	1.3	1.2	1.0	.8	.8
2 (7/1)	32	.6	1.0	1.5	2.0	2.7	3.6	3.9	3.7	2.4
	60	.5	.8	1.3	1.7	2.3	2.8	2.7	2.4	2.2
	90	.2	.5	.8	1.1	1.6	1.7	1.4	1.2	1.0
4 (6/1)	32	1.1	1.9	2.6	2.1	1.8	1.6	1.5	1.4	1.4
	60	1.0	1.6	1.8	1.4	1.1	.9	.9	.8	.5
	90	.7	1.2	.9	.5	.4	.3	.2	.2	.1
4 (7/1)	32	.8	1.3	2.0	2.8	2.5	2.4	2.0	1.8	1.7
	60	.7	1.1	1.6	1.9	1.6	1.4	1.2	1.1	1.1
	90	.5	.8	1.2	.9	.6	.6	.4	.4	.3

[1] See footnotes at end of table.

TABLE D14.—*Changes in midspan sags of conductors (unloaded conditions) Aluminum Cable Steel Reinforced*—Continued

MEDIUM-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent of the ultimate strength of the conductors.]

Conductor size and stranding	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
AWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2/0 (6/1)	32	0.6	0.6	1.1	1.3	1.7	2.0	2.4	2.6	3.1	3.5	4.0	4.6	5.1	5.9	6.4
	60	.3	.3	.5	.6	1.0	1.2	1.5	1.7	2.1	2.5	3.0	3.5	3.9	4.4	5.0
	90	−.1	−.2	−.1	−.1	.1	.3	.5	.6	.9	1.3	1.6	2.0	2.4	2.9	3.2
1/0 (6/1)	32	.4	.6	1.0	1.3	1.7	2.0	2.4	2.9	3.4	4.1	4.7	5.4	5.9	6.6	7.4
	60	.2	.4	.6	.8	1.1	1.4	1.7	2.2	2.6	3.1	3.6	4.2	4.8	5.4	6.0
	90	−.2	.0	.0	.0	.3	.5	.8	1.1	1.5	1.9	2.3	2.8	3.3	3.8	4.0
1 (6/1)	32	.5	.7	1.0	1.5	1.7	2.1	2.8	3.3	4.0	4.8	5.6	6.7	7.0	7.3	7.3
	60	.3	.4	.7	1.0	1.3	1.6	2.2	2.7	3.2	3.9	4.7	5.8	5.7	5.8	5.6
	90	−.1	−.1	.1	.4	.6	.8	1.4	1.8	2.2	2.7	3.3	3.8	3.9	4.0	3.8
2 (6/1)	32	.6	.8	1.0	1.4	1.9	2.4	3.0	3.7	4.5	5.2	5.8	6.1	6.1	6.1	5.9
	60	.4	.6	.7	1.1	1.5	1.9	2.4	3.0	3.7	4.1	4.4	4.4	4.3	4.3	4.0
	90	−.1	.1	.2	.5	.8	1.1	1.5	1.9	2.4	2.7	2.8	2.9	2.8	2.9	2.5
2 (7/1)	32	.4	.6	.9	1.1	1.5	1.8	2.2	2.6	3.2	3.8	4.4	5.1	6.0	6.7	6.8
	60	.3	.4	.6	.8	1.1	1.3	1.6	2.0	2.5	3.0	3.5	4.1	4.6	4.8	5.0
	90	−.1	−.1	.0	.1	.4	.6	.9	1.2	1.5	1.9	2.3	2.7	3.0	2.9	3.1
4 (6/1)	32	.5	.9	1.3	2.0	2.8	3.7	4.7	5.0	4.7	4.5	4.0	4.1	3.8	3.5	3.7
	60	.4	.7	1.1	1.8	2.4	3.2	3.7	3.7	3.3	3.1	2.8	2.9	2.4	2.4	2.3
	90	.1	.4	.7	1.2	1.8	2.5	2.6	2.4	1.9	1.8	1.7	1.4	1.4	1.2	1.3
4 (7/1)	32	.5	.6	.9	1.2	1.8	2.5	3.1	4.1	5.0	5.2	5.3	5.2	4.9	5.0	4.5
	60	.3	.4	.7	1.0	1.5	2.1	2.7	3.5	3.9	3.9	3.8	3.5	3.4	3.5	2.9
	90	.0	.1	.3	.5	1.0	1.5	2.0	2.5	2.6	2.4	2.2	2.0	1.7	2.0	1.5

LIGHT-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 50 percent of the ultimate strength of the conductors.]

Conductor size and stranding	Initial temperature	Sag increase for various span lengths in feet																
		200[1]	250	300	350	400	450	500	550	600	650	700	750	800	900	1,000	1,100	1,200
AWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2/0 (6/1)	30	0.3	0.4	0.7	0.8	1.0	1.3	1.5	1.9	2.1	2.4	2.6	2.9	3.2	3.7	4.3	4.7	5.2
	60	.1	.2	.3	.3	.4	.5	.7	.8	1.0	1.2	1.4	1.4	1.6	1.9	2.4	2.8	3.2
	90	−.3	−.3	−.4	−.5	−.6	−.5	−.5	−.4	−.4	−.3	−.2	−.2	.0	.1	.4	.7	.8
1/0 (6/1)	30	.3	.4	.7	.8	1.0	1.3	1.6	1.8	2.2	2.4	2.8	3.0	3.4	4.1	4.9	5.6	6.2
	60	.1	.1	.3	.3	.4	.6	.7	.8	1.1	1.2	1.5	1.7	2.0	2.5	3.2	3.5	4.1
	90	−.3	−.4	−.4	−.5	−.5	−.4	−.3	−.3	−.2	−.2	−.1	.1	.2	.6	1.2	1.4	1.6
1 (6/1)	30	.3	.4	.6	.8	1.1	1.3	1.6	2.0	2.2	2.6	3.0	3.3	3.5	4.4	4.8	5.5	5.8
	60	.1	.1	.2	.4	.5	.6	.9	1.1	1.2	1.5	1.8	2.0	2.2	2.7	3.1	3.5	3.5
	90	−.3	−.3	−.3	−.3	−.2	−.2	−.1	.0	.0	.2	.5	.6	.7	.9	1.1	1.1	1.1
2 (6/1)	30	.3	.5	.7	.9	1.1	1.4	1.6	1.9	2.3	2.6	3.0	3.3	3.7	4.4	5.1	5.4	5.6
	60	.1	.2	.3	.4	.5	.7	.9	1.1	1.4	1.7	1.9	2.2	2.5	2.9	3.2	3.5	3.4
	90	−.3	−.3	−.3	−.3	−.3	−.1	−.1	.0	.2	.3	.5	.7	.9	1.0	1.3	1.3	1.4
2 (7/1)	30	.3	.5	.6	.8	1.0	1.2	1.4	1.6	1.9	2.2	2.5	2.8	3.2	3.6	4.5	5.1	5.7
	60	.1	.2	.2	.3	.5	.6	.7	.9	1.0	1.2	1.4	1.6	2.0	2.3	3.1	3.3	3.7
	90	−.3	−.3	−.4	−.3	−.3	−.3	−.2	−.2	−.1	.0	.1	.3	.5	.6	1.2	1.4	1.6
4 (6/1)	30	.3	.5	.6	.9	1.1	1.4	1.7	2.2	2.6	3.1	3.8	4.3	4.7	5.3	5.5	5.2	5.1
	60	.1	.2	.3	.5	.7	.9	1.2	1.5	1.9	2.3	2.6	2.9	2.9	3.5	3.5	3.5	3.1
	90	−.2	−.2	−.3	−.1	.0	.2	.3	.6	.9	1.1	1.2	1.2	1.2	1.5	1.5	1.5	1.2
4 (7/1)	30	.2	.4	.5	.7	1.0	1.2	1.5	1.7	2.1	2.3	2.7	3.1	3.5	4.7	5.4	6.0	6.3
	60	.1	.2	.3	.4	.5	.7	.9	1.1	1.3	1.5	1.8	2.1	2.5	2.8	3.5	3.8	4.0
	90	−.2	−.2	−.3	−.2	−.2	−.1	.0	.1	.3	.4	.6	.8	1.1	1.2	1.5	1.6	1.8

[1] For spans shorter than 200 ft the values given for 200 ft are approximately correct.

TABLE D15.—*Changes in midspan sags of conductors (unloaded conditions) hard-drawn copper*

HEAVY-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent of the ultimate strength of the conductors.]

Conductor size and stranding	Initial temperature	Sag increase for various span lengths in feet								
		200 [1]	250	300	350	400	450	500	550	600
AWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2/0-7	30	0.5	0.7	1.0	1.3	1.7	2.0	2.5	2.7	2.8
	60	.2	.4	.6	.8	1.1	1.3	1.5	1.6	1.7
	90	−.1	.0	.1	.2	.4	.5	.7	.6	.6
1/0-7	30	.5	.7	1.1	1.5	2.0	2.3	2.6	2.8	2.8
	60	.3	.5	.7	1.0	1.3	1.5	1.6	1.6	1.8
	90	.0	.1	.3	.5	.6	.7	.7	.6	.8
1-7	30	.5	.8	1.3	1.9	2.3	2.4	2.6	2.6	2.6
	60	.4	.6	.9	1.3	1.5	1.6	1.7	1.7	1.7
	90	.1	.3	.4	.6	.7	.7	.8	.8	.8
2-3	30	.5	1.1	1.6	1.9	2.0	2.0	2.0	1.9	1.9
	60	.3	.7	1.1	1.2	1.3	1.3	1.3	1.2	1.2
	90	.2	.3	.4	.4	.4	.4	.5	.4	.5
4-3	30	1.2	1.7	1.6	1.5	1.5	1.5	1.4	1.4	1.3
	60	.8	1.1	1.0	1.0	1.0	1.0	.9	1.0	.9
	90	.4	.5	.5	.5	.5	.5	.4	.5	.4
4 (solid)	30	.9	1.9	2.2	2.2	2.0	2.0	1.9	1.8	1.9
	60	.7	1.4	1.6	1.4	1.4	1.3	1.3	1.3	1.3
	90	.4	.8	.9	.8	.8	.8	.8	.7	.8
6 (solid)	30	1.8	1.7	1.4	1.4	1.4	1.3	1.3	1.2	1.2
	60	1.3	1.2	1.0	1.0	1.0	.9	1.0	.9	.9
	90	.8	.8	.6	.6	.7	.6	.6	.5	.5
8 (solid)	30	1.1	.9	1.0	.8	.9	.9	.9	.9	.9
	60	.8	.7	.7	.6	.7	.7	.7	.7	.7
	90	.5	.5	.5	.4	.4	.4	.5	.5	.5

MEDIUM-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent of the ultimate strength of the conductors]

Conductor size and stranding	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
AWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2/0–7	30	0.3	0.5	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.0	2.0	2.3	2.3	2.4	2.5
	60	.1	.2	.4	.4	.5	.6	.7	.8	.9	.9	1.0	1.1	1.1	1.2	1.2
	90	–.2	–.2	–.2	–.2	–.2	–.2	–.2	–.2	–.2	–.2	–.2	–.1	–.2	–.1	.5
1/0–7	30	.4	.6	.8	1.0	1.3	1.5	1.8	1.9	2.1	2.4	2.5	2.8	2.9	3.0	3.5
	60	.2	.3	.3	.5	.7	.8	.9	.9	1.0	1.3	1.3	1.5	1.6	1.5	1.5
	90	–.2	–.2	–.2	–.2	–.2	–.1	.0	.0	.0	.1	.2	.3	.3	.2	.3
1–7	30	.4	.6	.9	1.2	1.4	1.7	1.9	2.2	2.5	2.7	2.9	3.1	3.2	3.4	3.5
	60	.2	.3	.4	.5	.7	.9	1.0	1.2	1.5	1.6	1.7	1.9	2.0	2.1	2.1
	90	–.1	–.1	–.1	.0	.0	.1	.1	.2	.4	.4	.5	.6	.6	.7	.7
2–3	30	.4	.5	.8	1.0	1.4	1.8	2.2	2.5	2.7	2.9	2.9	2.8	2.8	------	------
	60	.1	.2	.4	.7	.9	1.1	1.3	1.5	1.6	1.7	1.7	1.7	1.7	------	------
	90	–.1	–.1	.0	.0	.2	.3	.4	.6	.6	.6	.6	.5	.5	------	------
4–3	30	.4	.7	1.0	1.6	2.0	2.3	2.4	2.4	2.4	2.4	2.5	2.5	2.5	2.5	2.4
	60	.2	.4	.7	1.1	1.3	1.4	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.5
	90	.0	.2	.3	.4	.5	.5	.6	.6	.6	.7	.7	.7	.7	.7	.7
4 (solid)	30	.5	.7	1.1	1.4	2.1	2.6	3.0	3.2	3.3	3.4	3.4	3.3	3.3	------	------
	60	.2	.4	.7	1.0	1.5	1.9	2.1	2.1	2.3	2.4	2.4	2.3	2.3	------	------
	90	.0	.1	.3	.5	.8	1.1	1.1	1.2	1.3	1.2	1.2	1.1	1.3	------	------
6 (solid)	30	.5	.9	1.6	2.5	2.8	2.7	2.7	2.6	2.5	2.5	2.5	2.4	2.4	------	------
	60	.3	.7	1.2	1.8	1.9	1.9	1.8	1.8	1.7	1.8	1.8	1.7	1.7	------	------
	90	.1	.4	.7	1.0	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	------	------
8 (solid)	30	.9	2.1	2.3	2.2	2.0	1.9	1.9	1.8	1.8	1.8	1.7	1.7	1.7	------	------
	60	.8	1.6	1.6	1.5	1.4	1.3	1.4	1.3	1.3	1.3	1.3	1.3	1.3	------	------
	90	.5	1.0	1.0	.9	.8	.8	.9	.8	.8	.8	.8	.8	.8	------	------

See footnote at end of table.

TABLE D15—*Changes in midspan sags of conductors (unloaded conditions) hard-drawn copper*—Continued

LIGHT-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F,4. Loaded tensions do not exceed 50 percent of the ultimate strength of the conductors.]

Conductor size and stranding	Initial temperature	Sag increase for various span lengths in feet																
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	900	1,000	1,100	1,200
AWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2/0-7	30	0.4	0.5	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.5	1.5	1.6	1.7	1.7	1.7	1.8
	60	.1	.2	.2	.2	.3	.2	.3	.3	.3	.3	.3	.2	.3	.4	.3	.4	.4
	90	-.2	-.3	-.4	-.5	-.5	-.7	-.7	-.8	-.8	-.8	-.8	-1.0	-.9	-1.1	-1.0	-1.0	-.9
1/0-7	30	.4	.5	.6	.8	1.0	1.2	1.2	1.3	1.4	1.6	1.6	1.7	1.8	1.8	1.8	1.8	1.9
	60	.1	.2	.1	.2	.2	.3	.3	.2	.4	.4	.4	.4	.5	.5	.5	.5	.5
	90	-.2	-.2	-.5	-.5	-.5	-.6	-.7	-.8	-.8	-.7	-.8	-.8	-.8	-.8	-.8	-1.0	-.9
1-7	30	.3	.5	.7	.8	.9	1.1	1.2	1.4	1.5	1.6	1.7	1.8	1.9	1.9	1.9	......	......
	60	.1	.2	.2	.3	.2	.3	.3	.4	.5	.5	.5	.6	.6	.5	.6	......	......
	90	-.2	-.3	-.4	-.5	-.6	-.6	-.7	-.7	-.7	-.7	-.6	-.6	-.7	-.8	-.8	......	......
2-3	30	.3	.4	.6	.7	.9	1.0	1.1	1.4	1.6	1.8	1.9	2.1	2.3	2.4	2.6	......	......
	60	.1	.1	.2	.3	.3	.3	.4	.5	.6	.7	.8	.9	1.0	1.0	1.1	......	......
	90	-.2	-.3	-.2	-.3	-.3	-.5	-.5	-.5	-.4	-.4	-.4	-.3	-.3	-.5	-.3	......	......
4-3	30	.3	.4	.6	.8	1.0	1.2	1.5	1.7	2.0	2.1	2.2	2.2	2.4	2.5	2.5	2.5	2.5
	60	.1	.1	.3	.3	.4	.5	.7	.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2
	90	-.1	-.1	-.2	-.2	-.2	-.2	-.2	-.1	-.1	-.2	-.2	-.2	-.2	-.1	-.1	-.2	-.2
4 (solid)	30	.3	.4	.6	.8	.9	1.1	1.3	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.4	......	......
	60	.0	.1	.1	.3	.3	.4	.5	.6	.6	.7	.7	.7	.8	.8	1.0	......	......
	90	-.2	-.3	-.5	-.4	-.5	-.5	-.5	-.6	-.6	-.5	-.6	-.6	-.5	-.5	-.4	......	......
6 (solid)	30	.5	.5	.7	.9	1.1	1.3	1.6	1.8	2.0	2.3	2.5	2.7	2.8	3.0	3.2	3.2	3.2
	60	.1	.2	.2	.4	.5	.6	.7	.8	1.0	1.1	1.2	1.4	1.4	1.5	1.7	1.7	1.7
	90	-.3	-.3	-.3	-.3	-.3	-.3	-.2	-.3	-.2	-.1	.0	.2	.2	.2	.3	.3	.3
8 (solid)	30	.3	.5	.7	1.0	1.3	1.5	1.9	2.0	2.3	2.7	2.8	2.9	3.2	3.0	3.0	3.1	3.1
	60	.1	.2	.3	.5	.7	.8	1.1	1.1	1.3	1.6	1.6	1.7	1.8	1.7	1.8	1.7	1.8
	90	-.2	-.2	-.1	-.1	.0	.0	.2	.2	.2	.4	.4	.4	.5	.5	.5	.5	.5

[1] For spans shorter than 200 ft, the values given for 200 ft are approximately correct.

Table D16.—*Changes in midspan sags of conductors (unloaded conditions) Copperweld-copper*

HEAVY-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent of the ultimate strength of the conductors]

Conductor	Initial temperature	Sag increase for various span lengths in feet								
		200 [1]	250	300	350	400	450	500	550	600
	°F	ft	ft	ft	ft	ft	ft	ft	ft	ft
2 A	30	0.2	0.3	0.7	1.0	1.3	1.8	2.5	3.3	4.2
	60	.1	.2	.5	.7	1.0	1.4	2.1	2.8	3.5
	90	.0	.0	.3	.5	.7	1.0	1.6	2.2	2.9
4 A	30	.3	.4	.7	1.2	1.9	2.7	3.9	5.1	5.9
	30	.2	.3	.6	1.1	1.7	2.4	3.3	4.3	4.8
	90	.1	.2	.4	.8	1.4	2.0	2.8	3.5	3.8
6 A	30	.3	.6	1.1	2.3	3.9	4.6	4.9	4.6	4.4
	60	.2	.6	1.0	2.1	3.4	3.7	3.9	3.8	3.6
	90	.1	.5	.9	1.8	2.8	2.9	3.0	2.9	2.9
8 A	30	.2	.7	1.2	2.8	4.5	4.8	4.4	4.1	4.0
	60	.2	.6	1.1	2.5	3.8	3.9	3.7	3.4	3.3
	90	.2	.5	1.0	2.3	3.1	3.1	2.9	2.7	2.6
9½ D	30	.3	1.2	2.7	3.2	2.7	2.1	2.2	2.3	2.1
	60	.2	.9	2.2	2.4	2.0	1.7	1.7	1.9	1.6
	90	.2	.8	1.6	1.7	1.5	1.2	1.3	1.5	1.2
3 No. 12 CW	30	.1	.3	.8	2.2	2.9	2.7	2.5	2.3	2.2
	60	.1	.3	.6	1.8	2.2	2.1	1.9	1.8	1.7
	90	.1	.1	.4	1.3	1.5	1.5	1.3	1.2	1.1

[1] See footnote at end of table.

TABLE D16.—*Changes in midspan sags of conductors (unloaded condition) Copperweld-copper*—Continued

MEDIUM-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent of the ultimate strength of the conductors]

Conductor	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
	°F	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2 A	30	0.2	0.3	0.5	0.6	0.8	1.0	1.3	1.6	1.8	2.3	2.6	3.1	3.4	3.9	4.4
	60	.1	.2	.3	.3	.4	.5	.7	.9	1.0	1.4	1.7	2.1	2.3	2.7	3.2
	90	−.1	−.1	−.2	−.1	−.1	−.1	.1	.1	.2	.5	.8	1.0	1.3	1.6	2.0
4 A	30	.2	.2	.3	.6	.9	1.2	1.5	2.0	2.3	2.9	3.4	4.2	4.9	5.7	6.5
	60	.1	.0	.1	.2	.5	.7	1.0	1.5	1.7	2.2	2.8	3.4	4.1	4.8	5.5
	90	−.1	−.1	−.2	.0	.1	.3	.5	.9	1.1	1.5	2.0	2.5	3.2	3.7	4.3
6 A	30	.2	.3	.5	.7	1.1	1.5	2.0	2.6	3.5	4.3	5.5	6.3	6.9	7.2	7.5
	60	.1	.1	.2	.5	.8	1.2	1.6	2.2	3.0	3.7	4.6	5.3	5.8	6.1	6.3
	90	.0	−.1	.1	.2	.5	.9	1.2	1.7	2.4	3.1	3.7	4.2	4.5	4.7	4.8
8 A	30	.1	.3	.5	.7	1.0	1.4	2.0	2.8	3.7	5.1	6.2	6.9	7.3	7.5	7.4
	60	.0	.2	.3	.5	.7	1.2	1.7	2.4	3.3	4.4	5.3	5.9	6.1	6.2	6.1
	90	.0	.1	.2	.4	.5	.9	1.4	2.0	2.8	3.7	4.3	4.7	4.8	4.9	4.8
9½ D	30	.2	.2	.4	.6	1.0	1.6	2.8	3.7	4.6	5.0	5.1	4.9	4.4	4.2	4.1
	60	.1	.1	.3	.4	.8	1.3	2.2	3.0	3.6	3.8	3.9	3.8	3.4	3.3	3.2
	90	.0	−.1	.1	.1	.5	1.1	1.7	2.1	2.5	2.8	2.9	2.8	2.4	2.3	2.2
3 No. 12 CW	30	.1	.2	.2	.4	.6	.8	1.0	1.6	2.4	3.2	4.1	4.8	5.3	5.1	4.3
	60	.0	.1	.1	.3	.4	.6	.8	1.2	1.9	2.5	3.2	3.6	3.8	3.7	3.2
	90	.0	.0	.0	.1	.2	.4	.6	.9	1.2	1.7	2.0	2.3	2.4	2.3	2.2

LIGHT-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 50 percent of the ultimate strength of the conductors]

Conductor	Initial temperature	Sag increase for various span lengths, in feet																
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	900	1,000	1,100	1,200
	° F	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2 A	30	0.2	0.2	0.4	0.5	0.7	0.8	1.0	1.1	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.7
	60	.1	.0	.2	.2	.2	.2	.3	.3	.4	.5	.5	.6	.6	.8	.8	.8	1.0
	90	−.1	−.2	−.2	−.3	−.3	−.4	−.5	−.6	−.5	−.5	−.5	−.6	−.6	−.6	−.6	−.7	−.6
4 A	30	.2	.3	.3	.3	.6	.8	.9	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.5	2.8	3.1
	60	.0	.1	.1	.0	.1	.2	.4	.4	.4	.5	.6	.6	.8	.9	1.1	1.3	1.5
	90	−.1	−.1	−.3	−.3	−.4	−.3	−.4	−.5	−.4	−.5	−.5	−.5	−.5	−.4	−.3	−.3	−.1
6 A	30	.1	.2	.3	.5	.6	.7	.8	.9	1.3	1.3	1.5	1.8	2.0	2.4	3.0	3.6	4.3
	60	.0	.1	.1	.2	.2	.2	.2	.3	.4	.5	.6	.8	.9	1.2	1.7	2.2	2.6
	90	−.1	−.2	−.3	−.2	−.3	−.3	−.4	−.4	−.4	−.4	−.4	−.2	−.1	.0	.3	.6	1.0
8 A	30	.1	.2	.3	.4	.5	.6	.7	.9	1.0	1.2	1.4	1.6	1.9	2.6	3.2	3.9	4.5
	60	.0	−.1	.0	.1	.2	.3	.3	.4	.5	.6	.7	.8	1.0	1.5	2.0	2.6	3.0
	90	−.1	−.2	−.2	−.2	−.2	−.2	−.2	−.2	−.2	−.3	−.2	−.2	−.1	.3	.7	1.1	1.5
9½ D	30	.2	.2	.3	.4	.5	.6	.8	.9	1.1	1.3	1.5	1.8	2.0	2.6	3.2	3.8	4.2
	60	.1	.1	.1	.2	.2	.3	.3	.4	.5	.6	.8	1.0	1.2	1.6	2.0	2.3	2.6
	90	−.1	−.1	−.2	−.2	−.2	−.2	−.2	−.3	−.2	−.1	−.1	.1	.2	.5	.7	.9	1.0
3 No. 12 CW	30	.3	.2	.2	.4	.4	.4	.5	.6	.7	.8	1.0	1.2	1.3	1.7	2.2	2.6	3.1
	60	.2	.1	.1	.1	.1	.1	.1	.3	.3	.4	.4	.5	.6	.9	1.2	1.4	1.8
	90	.1	−.1	−.1	−.1	−.2	−.3	−.3	−.2	−.3	−.3	−.3	−.2	−.2	−.1	.1	.2	.5

[1] For spans shorter than 200 ft, the values given for 200 ft are approximately correct.

TABLE D17.—*Changes in midspan sags of conductors (unloaded conditions) Amerductor, type SCP or SCG*

[Values are calculated from curves and data copyrighted 1941 by the American Steel & Wire Company of New Jersey. Loading and tension limitations conform to rules 251 and 261, F, 4]

HEAVY-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F on basis of loaded tension not exceeding 60 percent of ultimate strength of conductors]

Conductor	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2	30	0.3	0.4	0.7	0.9	1.2	1.6	2.2	2.6	3.4	4.1	4.7	5.3	5.6	5.9	5.8
	60	.2	.3	.5	.6	1.0	1.2	1.8	2.2	2.8	3.3	3.8	4.2	4.4	4.6	4.5
	90	.1	.2	.3	.4	.6	.9	1.3	1.6	2.2	2.5	2.7	3.0	3.0	3.0	3.0
4	30	.2	.4	.8	1.0	1.6	2.3	3.0	4.3	5.4	6.4	6.8	6.8	6.8	6.7	6.6
	60	.1	.3	.6	.9	1.5	2.1	2.8	3.8	4.8	5.5	5.7	5.8	5.6	5.6	5.5
	90	.0	.2	.4	.8	1.3	1.8	2.5	3.2	4.0	4.4	4.5	4.6	4.5	4.4	4.3
6	30	.2	.8	1.0	1.8	2.8	4.7	6.5	7.5	7.6	7.4	6.9	6.7	6.5	6.3	6.1
	60	.2	.6	.9	1.6	2.6	4.4	5.9	6.7	6.6	6.3	5.9	5.7	5.6	5.6	5.3
	90	.1	.5	.8	1.4	2.4	4.0	5.4	5.7	5.5	5.3	5.1	4.9	4.7	4.7	4.5
8	30	.4	.9	1.7	3.8	6.2	7.7	7.4	6.6	6.4	6.3	5.9	5.7	5.7	5.8	5.5
	60	.4	.8	1.6	3.6	5.8	7.1	6.7	5.9	5.9	5.7	5.3	5.0	5.2	5.2	5.0
	90	.3	.7	1.5	3.5	5.4	6.4	6.0	5.3	5.3	5.0	4.8	4.4	4.7	4.7	4.5
8X	30	.1	.1	.2	.4	.6	1.2	1.9	2.1	2.2	2.2	1.8	1.7	1.7	1.7	1.7
	60	.0	.0	.1	.2	.3	.7	1.1	1.2	1.3	1.4	1.2	1.0	1.0	.9	.9
	90	−.1	−.1	.0	.0	.0	.1	.3	.4	.5	.5	.4	.2	.2	.3	.3
9X	30	.1	.1	.2	.6	1.2	2.4	3.0	2.7	2.6	2.5	2.4	2.4	2.2	2.1	2.1
	60	.0	.1	.2	.5	.9	2.0	2.2	2.1	2.0	1.9	1.8	1.8	1.6	1.5	1.5
	90	.0	.0	.1	.4	.6	1.5	1.4	1.4	1.3	1.2	1.2	1.1	1.0	.9	.9
10	30	.1	.2	.2	.4	.6	.9	1.2	1.7	2.8	4.4	6.2	7.4	8.0	8.2	7.7
	60	.0	.1	.2	.3	.4	.7	1.0	1.5	2.5	4.0	5.5	6.5	6.8	6.8	6.5
	90	.0	.1	.1	.2	.3	.6	.9	1.4	2.3	3.6	4.8	5.4	5.6	5.4	5.2
12	30	.1	.2	.3	.4	1.1	2.0	4.1	4.6	4.0	3.8	3.6	3.5	3.0	3.0	2.9
	60	.1	.1	.2	.4	1.0	1.5	3.4	3.8	3.4	3.1	2.9	2.7	2.2	2.2	2.1
	90	.0	.1	.2	.3	.8	.9	2.5	2.9	2.7	2.4	2.2	1.9	1.5	1.5	1.5

MEDIUM-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F on basis of loaded tension not exceeding 60 percent of ultimate strength of conductors]

Conductor	Initial temperature	Sag increase for various span lengths in feet														
		200[1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
	°F	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2	30	0.1	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.2	2.6	3.0	3.2	3.6	4.0
	60	.0	.2	.2	.3	.4	.6	.8	1.0	1.3	1.6	2.1	2.2	2.4	2.7	3.0
	90	−.1	.0	.0	.1	.1	.2	.4	.5	.7	.8	1.2	1.4	1.6	1.8	2.0
4	30	.2	.2	.3	.6	.8	1.1	1.3	1.7	2.0	2.6	3.0	3.7	4.3	5.0	5.5
	60	.1	.1	.2	.4	.6	.9	1.0	1.4	1.6	2.1	2.5	3.1	3.6	4.2	4.7
	90	.0	.0	.0	.2	.4	.6	.7	1.0	1.2	1.6	1.9	2.4	2.9	3.4	3.8
6	30	.2	.3	.5	.8	1.0	1.4	1.9	2.6	3.2	4.0	4.8	5.8	7.0	8.2	9.4
	60	.1	.2	.4	.6	.8	1.2	1.7	2.2	2.8	3.6	4.3	5.3	6.4	7.5	8.5
	90	.0	.1	.3	.4	.6	1.0	1.4	1.8	2.4	3.2	3.8	4.8	5.8	6.8	7.5
8	30	.1	.3	.5	.8	1.2	1.9	2.6	3.5	4.8	6.6	8.0	9.2	10.2	10.8	11.6
	60	.0	.2	.4	.6	1.0	1.7	2.4	3.2	4.4	6.2	7.5	8.5	9.3	9.7	10.4
	90	.0	.1	.3	.5	.9	1.5	2.2	3.0	4.1	5.7	6.8	7.6	8.4	8.6	9.2
8X	30	−.2	.0	.1	.2	.3	.4	.6	.6	.8	1.0	1.2	1.8	2.1	2.4	2.7
	60	−.2	−.1	.0	.1	.2	.2	.3	.3	.4	.6	.7	1.0	1.2	1.5	1.6
	90	−.3	−.2	−.1	.0	.0	.0	.0	.0	.1	.1	.2	.3	.3	.4	.4
9X	30	.0	.1	.2	.2	.3	.4	.6	.8	1.0	1.2	1.7	2.4	3.1	3.7	4.2
	60	.0	.0	.1	.1	.2	.3	.4	.6	.8	.8	1.3	1.8	2.2	2.6	3.0
	90	−.1	.0	.0	.0	.0	.1	.2	.3	.5	.5	.9	1.2	1.4	1.6	1.9
10	30	.1	.1	.2	3	.4	.4	.5	.7	.8	1.1	1.4	1.8	2.1	2.5	2.9
	60	.0	.0	.1	.2	.3	.3	.4	.5	.7	.9	1.2	1.5	1.8	2.1	2.5
	90	.0	.0	.1	.1	.2	.2	.2	.3	.5	.7	.9	1.2	1.4	1.8	2.1
12	30	.1	.1	.2	.2	.3	.4	.5	.8	1.2	1.4	1.8	2.6	3.8	4.8	5.8
	60	.0	.0	.1	.1	.2	.3	.4	.6	1.0	1.2	1.5	2.3	3.2	4.1	4.8
	90	.0	.0	.0	.0	.1	.2	.3	.5	.8	1.0	1.2	1.9	2.6	3.3	3.7

See footnote at end of table.

Table D17.—*Changes in midspan sags of conductors (unloaded conditions) Amerductor, type SCP or SCG*—Con.

LIGHT-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F on basis of loaded tension not exceeding 60 percent of ultimate strength of conductors]

Conductor	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
	°F	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft
2	30	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.1	1.4	1.5	1.6	1.8	2.0	2.2
	60	.0	.0	.1	.1	.2	.2	.4	.4	.5	.7	.7	.8	1.0	1.1	1.1
	90	−.1	−.1	−.1	−.1	−.2	−.2	−.1	−.1	−.1	−.1	−.1	−.1	.0	.0	.0
4	30	.1	.2	.3	.4	.5	.6	.8	.9	1.1	1.3	1.5	1.7	1.9	2.1	2.4
	60	.1	.1	.2	.2	.2	.3	.4	.5	.7	.8	.9	1.0	1.2	1.4	1.6
	90	.0	.0	.0	.0	.0	.0	.0	.0	.1	.2	.3	.4	.5	.6	.7
6	30	.0	.1	.2	.4	.5	.6	.8	.9	1.1	1.4	1.6	1.8	2.2	2.4	2.8
	60	.0	.0	.1	.2	.3	.4	.5	.6	.8	1.0	1.2	1.4	1.6	1.8	2.1
	90	−.1	−.1	.0	.0	.1	.2	.2	.3	.4	.5	.6	.8	.9	1.1	1.2
8	30	.1	.2	.2	.3	.4	.5	.7	1.0	1.1	1.4	1.7	2.0	2.4	2.8	3.2
	60	.0	.1	.1	.2	.2	.3	.5	.7	.9	1.1	1.3	1.6	1.9	2.2	2.5
	90	−.1	.0	.0	.0	.0	.1	.2	.4	.6	.7	.9	1.1	1.4	1.6	1.9
8X	30	.1	.1	.1	.1	.2	.3	.4	.4	.5	.5	.6	.7	.8	.9	1.0
	60	.0	.0	.0	.0	.0	.0	.0	.1	.1	.1	.1	.2	.2	.2	.3
	90	−.1	−.1	−.1	−.1	−.2	−.2	−.3	−.3	−.2	−.3	−.4	−.4	−.4	−.5	−.5
9X	30	.1	.1	.1	.1	.2	.2	.3	.4	.5	.6	.7	.8	.8	.9	1.0
	60	.0	.0	.0	.0	.0	.0	.1	.1	.2	.2	.3	.3	.3	.4	.4
	90	−.1	−.1	−.1	−.1	−.1	−.1	−.1	−.1	−.1	−.1	−.1	−.2	−.2	−.2	−.2
10	30	.1	.1	.1	.1	.1	.2	.2	.3	.4	.5	.6	.7	.8	.9	1.0
	60	.0	.0	.0	.0	.0	.1	.1	.1	.2	.2	.3	.4	.5	.5	.6
	90	.0	.0	.0	−.1	−.1	−.1	−.1	−.1	.0	.0	.0	.1	.1	.2	.2
12	30	.0	.1	.1	.2	.2	.2	.3	.3	.4	.5	.7	.8	1.0	1.1	1.3
	60	.0	.0	.0	.1	.1	.1	.1	.2	.2	.3	.4	.5	.6	.7	.8
	90	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.1	.2	.2	.3

[1] For spans shorter than 200 ft, the values given for 200 ft are approximately correct.

TABLE D18.—*Changes in midspan sags of conductors (unloaded conditions) Amersteel, three-wire and solid*

[Values are calculated from curves and data copyrighted 1943 by the American Steel & Wire Co. and the Indiana Steel & Wire Co. Loading and tension limitations conform to rules 251 and 261, F, 4]

HEAVY-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F on basis of loaded tension not exceeding 60 percent of ultimate strength of stranded and 50 percent of ultimate strength of solid conductors]

Conductor size and type	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
BWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
4 3S–130 (3-wire)	30	0.1	0.2	0.3	0.5	0.7	1.1	1.4	2.1	2.8	3.5	4.7	6.1	7.2	8.0	8.2
	60	.1	.1	.2	.4	.6	.9	1.3	1.9	2.5	3.2	4.3	5.5	6.4	7.1	7.2
	90	.0	.1	.1	.3	.5	.8	1.1	1.7	2.3	2.8	3.8	4.8	5.6	6.2	6.2
4 3S–80 (3-wire)	30	.4	.8	1.3	2.0	3.3	4.1	4.7	4.8	4.6	4.5	4.5	4.3	4.2	3.8	2.9
	60	.3	.7	1.2	1.7	3.1	3.6	4.0	4.1	3.8	3.8	3.8	3.8	3.6	3.2	2.4
	90	.2	.6	1.0	1.5	2.6	3.0	3.3	3.3	3.2	3.2	3.1	3.1	2.9	2.6	1.8
6 3S–130 (3-wire)	30	.1	.2	.3	.5	.8	1.2	1.7	3.3	4.4	5.6	6.5	6.5	6.5	6.5	6.1
	60	.1	.1	.3	.5	.7	1.1	1.5	3.0	4.0	5.1	5.7	5.8	5.6	5.5	5.2
	90	.0	.1	.2	.4	.6	.9	1.4	2.7	3.5	4.4	4.9	4.9	4.8	4.6	4.3
6 3S–80 (3-wire)	30	.6	1.2	2.4	3.5	3.9	3.7	3.5	3.4	3.3	3.2	3.2	3.1	3.1	3.0	3.0
	60	.5	1.1	2.2	3.0	3.3	3.1	3.0	2.9	2.8	2.8	2.7	2.7	2.7	2.6	2.6
	90	.4	1.1	2.0	2.6	2.7	2.6	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.2	2.2
4 S–130 (solid)	30	.2	.3	.4	.6	.9	1.5	2.4	3.4	4.1	-----	-----	-----	-----	-----	-----
	60	.1	.2	.4	.5	.8	1.3	2.1	2.9	3.4	-----	-----	-----	-----	-----	-----
	90	.1	.2	.3	.3	.6	1.0	1.7	2.4	2.7	-----	-----	-----	-----	-----	-----
4 S–80 (solid)	30	1.1	2.2	2.9	3.1	3.2	3.2	3.1	3.0	3.0	-----	-----	-----	-----	-----	-----
	60	1.0	2.0	2.5	2.5	2.6	2.6	2.5	2.5	2.5	-----	-----	-----	-----	-----	-----
	90	.9	1.8	2.0	2.0	2.0	2.0	2.0	2.0	2.0	-----	-----	-----	-----	-----	-----
6 S–130 (solid)	30	.2	.3	.5	.9	1.8	2.4	2.9	3.0	2.9	-----	-----	-----	-----	-----	-----
	60	.1	.2	.4	.7	1.4	1.9	2.2	2.3	2.1	-----	-----	-----	-----	-----	-----
	90	.1	.2	.2	.6	1.0	1.3	1.4	1.5	1.5	-----	-----	-----	-----	-----	-----
6 S–80 (solid)	30	1.2	1.5	1.9	1.8	1.8	1.8	1.6	-----	-----	-----	-----	-----	-----	-----	-----
	60	1.0	1.1	1.4	1.3	1.3	1.4	1.2	-----	-----	-----	-----	-----	-----	-----	-----
	90	.7	.8	.9	.9	.9	1.0	.8	-----	-----	-----	-----	-----	-----	-----	-----

See footnote at end of table.

TABLE D18.—*Changes in midspan sags of conductors (unloaded conditions) Amersteel, three-wire and solid*—Con.

MEDIUM-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F on basis of loaded tension not exceeding 60 percent of ultimate strength of stranded and 50 percent of ultimate strength of solid conductors]

Conductor size and type	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
BWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
4 3S–130 (3-wire)	30	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.3	1.6	1.9	2.2	2.7	3.2
	60	.0	.1	.1	.2	.2	.4	.4	.6	.8	1.0	1.2	1.5	1.8	2.2	2.7
	90	.0	.0	.0	.1	.1	.2	.2	.4	.5	.7	.9	1.2	1.5	1.7	2.1
4 3S–80 (3-wire)	30	.2	.3	.5	.8	1.1	1.6	2.1	2.6	3.2	3.9	4.7	5.2	5.8	6.2	6.5
	60	.1	.2	.4	.6	.9	1.3	1.8	2.2	2.8	3.4	4.1	4.5	5.0	5.3	5.5
	90	.1	.1	.3	.4	.6	1.0	1.4	1.7	2.3	2.7	3.4	3.7	4.1	4.2	4.4
6 3S–130 (3-wire)	30	.1	.1	.2	.3	.4	.5	.7	.9	1.1	1.5	1.8	2.2	2.6	3.1	3.7
	60	.0	.1	.1	.2	.3	.4	.5	.7	.9	1.3	1.5	1.8	2.3	2.7	3.2
	90	.0	.0	.0	.1	.1	.2	.3	.5	.6	.9	1.2	1.5	1.8	2.3	2.8
6 3S–80 (3-wire)	30	.2	.4	.7	.8	1.7	2.2	3.0	4.0	4.8	5.2	5.7	5.7	5.7	5.7	5.7
	60	.2	.4	.6	.6	1.5	1.9	2.7	3.6	4.2	4.5	4.8	4.9	4.8	4.8	4.8
	90	.1	.3	.4	.5	1.2	1.7	2.3	3.0	3.5	3.8	3.9	3.9	3.9	3.9	3.9
4 S–130 (solid)	30	.1	.2	.3	.4	.5	.8	1.0	1.2	1.4	1.8	2.1	2.4	2.8	3.4	4.1
	60	.1	.1	.2	.3	.4	.6	.8	.9	1.1	1.4	1.7	2.0	2.4	2.9	3.4
	90	.0	.1	.1	.2	.3	.4	.6	.7	.8	1.1	1.3	1.5	1.8	2.2	2.7
4 S–80 (solid)	30	.4	.7	1.0	1.6	2.3	3.0	3.6	4.1	4.3	4.6	4.7	4.8	4.8	4.9	5.0
	60	.3	.6	.9	1.4	2.0	2.5	3.0	3.4	3.5	3.8	3.9	3.9	3.9	4.1	4.1
	90	.2	.5	.7	1.2	1.7	2.0	2.4	2.6	2.7	2.9	3.0	3.0	3.0	3.1	3.1
6 S–130 (solid)	30	.1	.2	.3	.4	.5	.8	1.0	1.2	1.6	2.0	2.6	3.2	3.6	3.9	4.2
	60	.1	.1	.2	.2	.3	.5	.8	1.0	1.2	1.5	2.0	2.4	2.7	3.0	3.2
	90	.0	.1	.1	.1	.1	.3	.5	.6	.8	1.0	1.3	1.6	1.8	1.9	2.0
6 S–80 (solid)	30	.3	.6	1.0	1.6	2.2	2.6	2.8	2.9	2.9	2.9	2.8	------	------	------	------
	60	.2	.4	.8	1.2	1.7	2.0	2.1	2.2	2.2	2.1	2.1	------	------	------	------
	90	.1	.3	.6	.9	1.1	1.3	1.4	1.5	1.5	1.5	1.4	------	------	------	------

LIGHT-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F on basis of loaded tension not exceeding 60 percent of ultimate strength of stranded and 50 percent of ultimate strength of solid conductors]

Conductor size and type	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
BWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
4 3S–130 (3-wire)	30	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.3	1.4
	60	.0	.1	.1	.1	.1	.2	.2	.2	.3	.4	.4	.5	.6	.7	.8
	90	.0	.0	.0	.0	−.1	.0	.0	.0	.0	.0	.0	.1	.1	.2	.2
4 3S–80 (3 wire)	30	.1	.2	.3	.4	.5	.7	.9	1.0	1.1	1.4	1.8	2.1	2.4	2.8	2.8
	60	.1	.1	.2	.2	.3	.4	.6	.6	.8	.9	1.2	1.5	1.7	2.0	2.1
	90	.0	.0	.0	.0	.0	.1	.2	.2	.3	.4	.6	.8	1.0	1.2	1.2
6 3S–130 (3-wire)	30	.1	.1	.1	.2	.2	.2	.4	.5	.7	.7	.9	1.0	1.0	1.3	1.5
	60	.0	.0	.1	.1	.1	.1	.2	.2	.4	.4	.5	.6	.6	.8	1.0
	90	.0	.0	.0	.0	.0	−.1	.0	.0	.0	.0	.1	.1	.2	.3	.4
6 3S–80 (3-wire)	30	.1	.2	.3	.4	.6	.8	1.0	1.3	1.5	1.8	2.1	2.4	2.7	3.1	3.6
	60	.1	.1	.2	.3	.4	.6	.7	.9	1.1	1.4	1.6	1.8	2.1	2.4	2.9
	90	.0	.0	.0	.0	.1	.2	.3	.5	.6	.8	1.0	1.2	1.3	1.6	1.9
4 S–130 (solid)	30	.1	.2	.3	.4	.5	.6	.7	.9	1.0	1.2	1.3	1.5	1.7	1.9	2.0
	60	.1	.1	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3
	90	.0	.0	.0	.1	.1	.1	.1	.2	.2	.3	.4	.4	.5	.6	.6
4 S–80 (solid)	30	.3	.4	.5	.7	.9	1.2	1.4	1.7	1.9	2.2	2.4	2.7	3.0	3.2	3.4
	60	.2	.3	.4	.5	.6	.8	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4
	90	.0	.1	.2	.2	.3	.3	.4	.6	.7	.8	.9	1.0	1.2	1.3	1.4
6 S–130 (solid)	30	.1	.2	.3	.4	.5	.6	.7	.9	1.0	1.2	1.3	1.5	1.7	1.9	2.0
	60	.1	.1	.1	.2	.3	.4	.4	.6	.7	.8	.8	1.0	1.1	1.2	1.4
	90	.0	.0	.0	.1	.1	.1	.1	.2	.2	.2	.3	.3	.4	.4	.5
6 S–80 (solid)	30	.2	.3	.5	.7	.9	1.1	1.3	1.6	1.8	2.0	2.2	2.5	2.7	3.0	3.3
	60	.1	.2	.3	.5	.6	.7	.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.3
	90	.0	.0	.0	.1	.2	.2	.3	.4	.4	.6	.7	.8	.9	1.0	1.2

1 For spans shorter than 200 ft, the values given for 200 ft are approximately correct.

TABLE D19.—*Changes in midspan sags of conductors (unloaded conditions) Crapo, stranded three-wire, galvanized steel*

[Values are calculated from data copyrighted in 1943 by Indiana Steel & Wire Co.]

HEAVY-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent of the ultimate strength of the conductors]

Conductor size	Initial temperature	Sag increase for various span lengths in feet								
		200 [1]	250	300	350	400	450	500	550	600
BWG	*°F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
4-HTC-130	30	0.1	0.2	0.3	0.5	0.7	1.1	1.4	2.1	2.8
	60	.1	.1	.2	.4	.6	.9	1.3	1.9	2.5
	90	.0	.1	.1	.3	.5	.8	1.1	1.7	2.3
4-HTC-80	30	.4	.8	1.3	2.0	3.3	4.1	4.7	4.8	4.6
	60	.3	.7	1.2	1.7	3.1	3.6	4.0	4.1	3.8
	90	.2	.6	1.0	1.5	2.6	3.0	3.3	3.3	3.2
6-HTC-130	30	.1	.2	.3	.5	.8	1.2	1.7	3.3	4.4
	60	.1	.1	.3	.5	.7	1.1	1.5	3.0	4.0
	90	.0	.1	.2	.4	.6	.9	1.4	2.7	3.5
6-HTC-80	30	.6	1.2	2.4	3.5	3.9	3.7	3.5	3.4	3.3
	60	.5	1.1	2.2	3.0	3.3	3.1	3.0	2.9	2.8
	90	.4	1.1	2.0	2.6	2.7	2.6	2.4	2.4	2.3
8-HTC-130	30	.1	.3	.5	1.2	2.2	3.8	4.6	5.0	4.3
	60	.1	.2	.4	1.0	2.0	3.3	4.0	4.1	3.7
	90	.1	.1	.3	.9	1.8	2.8	3.2	3.2	3.0
8-HTC-80	30	1.4	2.8	2.8	2.6	2.5	2.3	2.2	----	----
	60	1.3	2.5	2.4	2.2	2.1	1.9	1.9	----	----
	90	1.2	2.1	2.0	1.8	1.8	1.6	1.6	----	----

MEDIUM-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent of the ultimate strength of the conductors]

Conductor size	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
BWG	*° F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
4-HTC-130	30	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.3	1.6	1.9	2.2	2.7	3.2
	60	.0	.1	.1	.2	.2	.4	.4	.6	.8	1.0	1.2	1.5	1.8	2.2	2.7
	90	.0	.0	.0	.1	.1	.2	.2	.4	.5	.7	.9	1.2	1.5	1.7	2.1
4-HTC-80	30	.2	.3	.5	.8	1.1	1.6	2.1	2.6	3.2	3.9	4.7	5.2	5.8	6.2	6.5
	60	.1	.2	.4	.6	.9	1.3	1.8	2.2	2.8	3.4	4.1	4.5	5.0	5.3	5.5
	90	.1	.1	.3	.4	.6	1.0	1.4	1.7	2.3	2.7	3.4	3.7	4.1	4.2	4.4
6-HTC-130	30	.1	.1	.2	.3	.4	.5	.7	.9	1.1	1.5	1.8	2.2	2.6	3.1	3.7
	60	.0	.1	.1	.2	.3	.4	.5	.7	.9	1.3	1.5	1.8	2.3	2.7	3.2
	90	.0	.0	.0	.1	.1	.2	.3	.5	.6	.9	1.2	1.5	1.8	2.3	2.8
6-HTC-80	30	.2	.4	.7	.8	1.7	2.2	3.0	4.0	4.8	5.2	5.7	5.7	5.7	5.7	5.7
	60	.2	.4	.6	.6	1.5	1.9	2.7	3.6	4.2	4.5	4.8	4.9	4.8	4.8	4.8
	90	.1	.3	.4	.5	1.2	1.7	2.3	3.0	3.5	3.8	3.9	3.9	3.9	3.9	3.9
8-HTC-130	30	.1	.1	.2	.3	.4	.6	.8	1.1	1.5	2.1	3.0	4.3	5.4	------	------
	60	.1	.1	.1	.2	.3	.4	.7	1.0	1.4	1.8	2.7	3.9	4.8	------	------
	90	.0	.0	.1	.1	.2	.3	.6	.8	1.2	1.6	2.3	3.3	4.1	------	------
8-HTC-80	30	.4	.7	1.3	2.0	3.1	4.2	4.5	4.5	4.5	4.4	4.2	------	------	------	------
	60	.3	.6	1.1	1.9	2.8	3.6	3.9	3.9	3.8	3.7	3.6	------	------	------	------
	90	.2	.5	1.0	1.7	2.4	3.0	3.2	3.1	3.1	3.0	2.9	------	------	------	------

See footnote at end of table.

TABLE D19.—*Changes in midspan sags of conductors (unloaded conditions) Crapo, stranded three-wire, galvanized steel*—Continued

LIGHT-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° Loading and tension limitations conform rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent of the ultimate strength of the conductors]

Conductor size	Initial temperature	Sag increase for various span lengths in feet																
		200[1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1,000
BWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
4-HTC-130	30	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.3	1.4	1.6	1.7
	60	.0	.1	.1	.1	.1	.2	.2	.2	.3	.4	.4	.5	.6	.7	.8	1.0	1.1
	90	.0	.0	.0	.0	—.1	.0	.0	.0	.0	.0	.0	.1	.1	.2	.2	.4	.4
4-HTC-80	30	.1	.2	.3	.4	.5	.7	.9	1.0	1.1	1.4	1.8	2.1	2.4	2.8	2.8	------	------
	60	.1	.1	.2	.2	.3	.4	.6	.6	.8	.9	1.2	1.5	1.7	2.0	2.1	------	------
	90	.0	.0	.0	.0	.0	.1	.2	.2	.3	.4	.6	.8	1.0	1.2	1.2	------	------
6-HTC-130	30	.1	.1	.1	.2	.2	.2	.4	.5	.7	.7	.9	1.0	1.0	1.3	1.5	1.6	1.9
	60	.0	.0	.1	.1	.1	.1	.2	.2	.4	.4	.5	.6	.6	.8	1.0	1.0	1.2
	90	.0	.0	.0	.0	.0	—.1	.0	.0	.0	.0	.1	.1	.2	.3	.4	.4	.5
6-HTC-80	30	.1	.2	.3	.4	.6	.8	1.0	1.3	1.5	1.8	2.1	2.4	2.7	3.1	3.6	------	------
	60	.1	.1	.2	.3	.4	.6	.7	.9	1.1	1.4	1.6	1.8	2.1	2.4	2.9	------	------
	90	.0	.0	.0	.0	.1	.2	.3	.5	.6	.8	1.0	1.2	1.3	1.6	1.9	------	------
8-HTC-130	30	.1	.1	.1	.2	.3	.3	.4	.5	.6	.7	.9	1.1	1.2	1.4	1.7	1.9	2.1
	60	.0	.0	.1	.1	.1	.2	.2	.3	.3	.5	.6	.7	.9	1.1	1.3	1.4	1.6
	90	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.2	.3	.4	.5	.7	.8	.9
8-HTC-80	30	.1	.3	.4	.5	.8	1.0	1.3	1.6	2.0	2.5	2.9	3.4	3.9	------	------	------	------
	60	.1	.2	.3	.4	.6	.8	1.0	1.4	1.7	2.2	2.4	2.9	3.3	------	------	------	------
	90	.0	.1	.1	.2	.3	.4	.6	.9	1.2	1.5	1.8	2.2	2.4	------	------	------	------

[1] For spans shorter than 200 ft, the values given for 200 ft are approximately correct.

Table D20.—*Changes in midspan sags of conductors (unloaded conditions) Crapo, solid, galvanized steel*

[Values are calculated from data copyrighted in 1943 by Indiana Steel & Wire Co.]

HEAVY-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60°F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 50 percent of the ultimate strength of the conductors]

Conductor size	Initial temperature	Sag increase for various span lengths in feet								
		200 [1]	250	300	350	400	450	500	550	600
BWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
4-HTC-130	30	0.2	0.3	0.4	0.6	0.9	1.5	2.4	3.4	4.1
	60	.1	.2	.4	.5	.8	1.3	2.1	2.9	3.4
	90	.1	.2	.3	.3	.6	1.0	1.7	2.4	2.7
4-HTC-80	30	1.1	2.2	2.9	3.1	3.2	3.2	3.1	3.0	3.0
	60	1.0	2.0	2.5	2.5	2.6	2.6	2.5	2.5	2.5
	90	.9	1.8	2.0	2.0	2.0	2.0	2.0	2.0	2.0
6 HTC-130	30	.2	.3	.5	.9	1.8	2.4	2.9	3.0	2.9
	60	.1	.2	.4	.7	1.4	1.9	2.2	2.3	2.1
	90	.1	.2	.2	.6	1.0	1.3	1.4	1.5	1.5
6-HTC-80	30	1.2	1.5	1.9	1.8	1.8	1.8	1.6		
	60	1.0	1.1	1.4	1.3	1.3	1.4	1.2		
	90	.7	.8	.9	.9	.9	1.0	.8		
8 HTC-130	30	.2	.6	1.5	1.7	1.7	1.6	1.5	1.5	1.4
	60	.1	.4	1.1	1.3	1.2	1.1	1.0	1.0	1.0
	90	.1	.3	.6	.8	.6	.6	.6	.5	.5
8 HTC-80	30	1.2	1.1	1.0	1.0	.9	.9	.9		
	60	.8	.8	.7	.7	.6	.6	.6		
	90	.5	.5	.5	.5	.4	.4	.4		

See footnote at end of table.

TABLE D20.—*Change in midspan sags of conductors (unloaded conditions) Crapo, solid, galvanized steel*—Con.

MEDIUM-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 50 percent of the ultimate strength of the conductors.]

Conductor size	Initial temperature	Sag increase for various span lengths in feet														
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900
BWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
4-HTC-130	30	0.1	0.2	0.3	0.4	0.5	0.8	1.0	1.2	1.4	1.8	2.1	2.4	2.8	3.4	4.1
	60	.1	.1	.2	.3	.4	.6	.8	.9	1.1	1.4	1.7	2.0	2.4	2.9	3.4
	90	.0	.1	.1	.2	.3	.4	.6	.7	.8	1.1	1.3	1.5	1.8	2.2	2.7
4-HTC-80	30	.4	.7	1.0	1.6	2.3	3.0	3.6	4.1	4.3	4.6	4.7	4.8	4.8	------	------
	60	.3	.6	.9	1.4	2.0	2.5	3.0	3.4	3.5	3.8	3.9	3.9	3.9	------	------
	90	.2	.5	.7	1.2	1.7	2.0	2.4	2.6	2.7	2.9	3.0	3.0	3.0	------	------
6-HTC-130	30	.1	.2	.3	.4	.5	.8	1.0	1.2	1.6	2.0	2.6	3.2	3.6	3.9	4.2
	60	.1	.1	.2	.2	.3	.5	.8	1.0	1.2	1.5	2.0	2.4	2.7	3.0	3.2
	90	.0	.1	.1	.1	.1	.3	.5	.6	.8	1.0	1.3	1.6	1.8	1.9	2.0
6-HTC-80	30	.3	.6	1.0	1.6	2.2	2.6	2.8	2.9	2.9	2.9	2.8	------	------	------	------
	60	.2	.4	.8	1.2	1.7	2.0	2.1	2.2	2.2	2.1	2.1	------	------	------	------
	90	.1	.3	.6	.9	1.1	1.3	1.4	1.5	1.5	1.5	1.4	------	------	------	------
8-HTC-130	30	.1	.2	.3	.4	.6	.9	1.5	2.1	2.6	2.8	2.9	2.9	3.0	------	------
	60	.1	.2	.2	.3	.4	.7	1.1	1.6	1.8	2.0	2.0	2.0	2.0	------	------
	90	.0	.0	.1	.1	.2	.5	.7	.9	1.0	1.0	1.1	1.1	1.1	------	------
8-HTC-80	30	.4	1.0	1.6	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	------	------	------
	60	.3	.8	1.2	1.3	1.3	1.2	1.3	1.3	1.2	1.2	1.2	1.2	------	------	------
	90	.2	.5	.7	.7	.7	.7	.8	.8	.7	.7	.7	.7	------	------	------

LIGHT-LOADING DISTRICT

[Increase from initial sag at temperatures given to final unloaded sag at 60° F. Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 50 percent of the ultimate strength of the conductors.]

Conductor size	Initial temperature	Sag increase for various span lengths in feet																
		200 [1]	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1,000
BWG	°*F*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
	30	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.7	1.9	2.0	2.2	2.4
4-HTC-130	60	.1	.1	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.7
	90	.0	.0	.0	.1	.1	.1	.1	.2	.2	.3	.4	.4	.5	.6	.6	.7	.8
	30	.3	.4	.5	.7	.9	1.2	1.4	1.7	1.9	2.2	2.4	2.7	3.0	3.2	3.4	3.6	3.8
4-HTC-80	60	.2	.3	.4	.5	.6	.8	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.7
	90	.0	.1	.2	.2	.3	.3	.4	.6	.7	.8	.9	1.0	1.2	1.3	1.4	1.5	1.6
	30	.1	.2	.3	.4	.5	.6	.7	.9	1.0	1.2	1.3	1.5	1.7	1.9	2.0	------	------
6-HTC-130	60	.1	.1	.1	.2	.3	.4	.4	.6	.7	.8	.8	1.0	1.1	1.2	1.4	------	------
	90	.0	.0	.0	.1	.1	.1	.1	.2	.2	.2	.3	.3	.4	.4	.5	------	------
	30	.2	.3	.5	.7	.9	1.1	1.3	1.6	1.8	2.0	2.2	2.5	2.7	3.0	3.3	3.3	3.4
6-HTC-80	60	.1	.2	.3	.5	.6	.7	.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.3	2.3	2.4
	90	.0	.0	.0	.1	.2	.2	.3	.4	.4	.6	.7	.8	.9	1.0	1.2	1.2	1.2
	30	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.3	1.4	1.5	1.6	1.9	2.1	2.2	2.4
8-HTC-130	60	.0	.1	.1	.2	.2	.3	.4	.4	.5	.8	.8	.9	.9	1.1	1.4	1.4	1.5
	90	.0	.0	.0	.0	.0	.0	.0	.0	.1	.2	.2	.3	.3	.4	.4	.5	.5
	30	.2	.4	.5	.7	.9	1.2	1.3	1.6	1.9	2.0	2.3	2.6	2.8	2.8	2.9	3.2	3.4
8-HTC-80	60	.1	.2	.3	.4	.6	.8	.9	1.1	1.2	1.3	1.5	1.7	1.8	1.9	2.0	2.2	2.3
	90	.0	.0	.0	.1	.2	.3	.3	.4	.5	.5	.7	.8	.8	.9	1.0	1.0	1.1

[1] For spans shorter than 200 ft, the values given for 200 ft are approximately correct.

Table D21—*Total sag of bare conductors for various spans*

HEAVY LOADING DISTRICT

[Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent or, where indicated, 50 percent of the ultimate strength of the conductors]

Conductor size, type, and stranding	Total sag for span lengths in feet				
	200	250	300	350	400
ALUMINUM CABLE STEEL REINFORCED					
AWG	*ft*	*ft*	*ft*	*ft*	*ft*
2 (6/1)	3.8	5.5	7.4	9.7	12.7
2 (7/1)	3.3	4.8	6.5	8.3	10.3
4 (6/1)	4.8	7.0	10.1	13.7	18.0
4 (7/1)	4.2	6.0	8.2	11.2	14.5
COPPER, STRANDED, HARD-DRAWN					
AWG					
2 – 3	3.3	5.1	7.3	10.0	13.1
3 – 3	3.9	6.0	8.6	11.7	15.4
4 – 3	4.6	7.2	10.3	14.2	18.6
COPPER, SOLID, HARD-DRAWN					
AWG					
2	3.0	4.7	6.7	9.2	12.1
4	4.2	6.5	9.5	12.9	16.9
6	6.0	9.5	13.7	18.8	24.7
8	9.0	14.2	20.7	28.8	38.2
COPPERWELD-COPPER					
2 A	2.4	3.5	4.8	6.2	7.8
4 A	3.0	4.3	5.8	7.5	9.5
6 A	3.7	5.4	7.4	9.9	12.9
8 A	4.0	5.9	8.0	10.9	14.3
9½ D	4.5	6.9	9.9	13.7	17.8
COPPERWELD					
AWG					
3 No. 12	4.1	5.8	7.7	10.5	13.7
STEEL-COPPER, 3-WIRE, AMERDUCTOR SCP OR SCG					
2	2.1	3.2	4.4	5.8	7.3
4	2.7	4.0	5.5	7.1	8.9
6	3.3	4.9	6.8	9.0	11.2
8	4.3	6.1	8.5	11.5	15.1
8 X	3.6	5.3	7.1	9.2	12.1
9 X	4.0	5.7	7.6	10.2	13.4

See footnote at end of table.

TABLE D21—*Total sag of bare conductors for various spans*—Continued

HEAVY-LOADING DISTRICT—continued

[Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent or, where indicated, 50 percent of the ultimate strength of the conductors]

Conductor size, type, and stranding	Total sag for span lengths in feet				
	200	250	300	350	400
AMERSTEEL, 3-WIRE, GALVANIZED					
BWG					
4 3S–130	2.2	3.3	4.5	5.9	7.4
6 3S–130	2.6	3.9	5.3	6.9	8.6
8 3S–130	3.4	4.9	6.6	8.7	11.3
4 3S–80	2.9	4.3	5.9	7.6	9.9
6 3S–80	3.5	5.1	7.3	9.9	13.0
8 3S–80	4.5	7.1	10.3	14.0	18.5
CRAPO, STRANDED, 3-WIRE, GALVANIZED STEEL					
BWG					
4 HTC–130	2.2	3.3	4.5	5.9	7.4
6 HTC–130	2.6	3.9	5.3	6.9	8.6
8 HTC–130	3.4	4.9	6.6	8.7	11.3
4 HTC–80	2.9	4.3	5.9	7.6	9.9
6 HTC–80	3.5	5.1	7.3	9.9	13.0
8 HTC–80	4.5	7.1	10.3	14.0	18.5
AMERSTEEL, SOLID, GALVANIZED					
BWG					
4 S–130 [1]	2.3	3.3	4.5	5.8	7.4
6 S–130 [1]	2.7	3.9	5.4	7.3	9.5
8 S–130 [1]	3.4	5.3	7.7	10.2	13.5
4 S–80 [1]	3.0	4.5	6.6	9.0	11.8
6 S–80 [1]	3.9	6.1	8.7	11.8	15.4
8 S–80 [1]	5.5	8.6	12.3	16.9	22.1
CRAPO, SOLID, GALVANIZED STEEL					
BWG					
4 HTC–130 [1]	2.3	3.3	4.5	5.8	7.4
6 HTC–130 [1]	2.7	3.9	5.4	7.3	9.5
8 HTC–130 [1]	3.4	5.3	7.7	10.2	13.5
4 HTC–80 [1]	3.0	4.5	6.6	9.0	11.8
6 HTC–80 [1]	3.9	6.1	8.7	11.8	15.4
8 HTC–80 [1]	5.5	8.6	12.3	16.9	22.1

[1] Based on maximun tension of 50 percent ultimate strength of conductors.

TABLE D22.—*Total sag of bare conductors for various spans*

MEDIUM-LOADING DISTRICT

[Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent or, where indicated, 50 percent of the ultimate strength of the conductors]

Conductor, size, type, and stranding	Total sag for span lengths in feet					
	200	250	300	350	400	450
ALUMINUM CABLE STEEL REINFORCED						
AWG	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2 (6/1)	2.8	4.0	5.4	6.8	8.4	10.2
2 (7/1)	2.5	3.5	4.8	6.1	7.5	9.1
4 (6/1)	3.4	4.9	6.5	8.3	10.3	12.5
4 (7/1)	3.0	4.3	5.8	7.3	9.0	10.9
COPPER, STRANDED, HARD-DRAWN						
AWG						
2–3	2.3	3.3	4.6	6.2	7.7	9.7
4–3	2.8	4.2	5.8	7.9	10.3	13.2
COPPER, SOLID, HARD-DRAWN						
AWG	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2	2.4	3.4	4.7	6.2	7.8	9.6
4	2.8	4.1	5.6	7.2	9.2	11.6
6	3.4	5.0	7.2	9.8	12.8	16.3
8	4.6	7.2	10.4	14.2	18.6	23.7
COPPERWELD-COPPER						
2 A	1.7	2.6	3.6	4.7	6.0	7.3
4 A	2.1	3.1	4.2	5.5	6.9	8.5
6 A	2.6	3.8	5.2	6.7	8.2	10.0
8 A	2.8	4.1	5.5	7.0	8.7	10.6
9½ D	3.1	4.5	6.0	7.7	9.6	11.8
COPPERWELD						
AWG						
3 No. 12	2.8	4.2	5.6	7.1	8.8	10.5
STEEL-COPPER, 3-WIRE, AMERDUCTOR SCP OR SCG						
2	1.5	2.2	3.1	4.1	5.3	6.6
4	1.8	2.6	3.7	4.8	6.2	7.7
6	2.2	3.3	4.5	6.0	7.5	9.2
8	2.7	4.1	5.6	7.3	9.2	11.2
8 X	2.3	3.5	4.9	6.4	8.0	9.7
9 X	2.7	3.9	5.3	6.9	8.6	10.4
AMERSTEEL, 3-WIRE, GALVANIZED						
BWG						
4 3S–130	1.7	2.4	3.0	3.9	5.0	6.1
6 3S–130	1.7	2.5	3.5	4.6	5.8	7.1
8 3S–130	2.2	3.3	4.4	5.8	7.1	8.7
4 3S–80	1.9	2.9	4.0	5.3	6.6	8.1
6 3S–80	2.3	3.4	4.7	6.2	7.8	9.5
8 3S–80	2.9	4.3	5.9	7.6	9.9	12.5

See footnote at end of table.

TABLE D22.—*Total sag of bare conductors for various spans*—Con.

MEDIUM-LOADING DISTRICT—continued

Conductor, size, type, and stranding	Total sag for span lengths in feet: 200	250	300	350	400	450
CRAPO, STRANDED, 3-WIRE, GALVANIZED STEEL						
BWG						
4 HTC–130	1.7	2.4	3.0	3.9	5.0	6.1
6 HTC–130	1.7	2.5	3.5	4.6	5.8	7.1
8 HTC–130	2.2	3.3	4.4	5.8	7.1	8.7
4 HTC–80	1.9	2.9	4.0	5.3	6.6	8.1
6 HTC–80	2.3	3.4	4.7	6.2	7.8	9.5
8 HTC–80	2.9	4.3	5.9	7.6	9.9	12.5
AMERSTEEL, SOLID, GALVANIZED						
BWG						
4 S–130 [1]	1.5	2.2	3.1	4.1	5.2	6.3
6 S–130 [1]	1.8	2.7	3.7	4.8	6.0	7.2
8 S–130 [1]	2.3	3.4	4.6	5.9	7.4	9.3
4 S–80 [1]	1.9	2.8	3.9	5.2	6.7	8.5
6 S–80 [1]	2.3	3.4	4.8	6.5	8.5	10.8
8 S–80 [1]	3.0	4.7	6.7	9.1	11.8	14.9
CRAPO, SOLID, GALVANIZED STEEL						
BWG						
4 HTC–130 [1]	1.5	2.2	3.1	4.1	5.2	6.3
6 HTC–130 [1]	1.8	2.7	3.7	4.8	6.0	7.2
8 HTC–130 [1]	2.3	3.4	4.6	5.9	7.4	9.3
4 HTC–80 [1]	1.9	2.8	3.9	5.2	6.7	8.5
6 HTC–80 [1]	2.3	3.4	4.8	6.5	8.5	10.8
8 HTC–80 [1]	3.0	4.7.	6.7	9.1	11.8	14.9

[1] Based on maximum tension of 50 percent of ultimate strength of conductors.

TABLE D23—*Total sag of bare conductors for various spans*

[Italic figures in parenthesis are given where sag at 120°F is greater]

LIGHT-LOADING DISTRICT

[Loading and tension limitations conform to rules 251 and 261, F, 4. Loaded tensions do not exceed 60 percent or, where indicated, 50 percent of the ultimate strength of the conductors]

Conductor size, type, and stranding	Total sag for span lengths in feet: 200	250	300	350	400	450	500
ALUMINUM CABLE STEEL REINFORCED							
AWG	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*	*ft*
2 (6/1) [1]	1.9 (*2.1*)	2.8	3.9	5.0	6.2	7.5	8.9
2 (7/1) [1]	1.7 (*1.9*)	2.5 (*2.6*)	3.4	4.5	5.5	6.8	8.1
4 (6/1) [1]	2.2	3.2	4.3	5.5	6.8	8.2	9.7
4 (7/1) [1]	1.9	2.8	3.8	4.9	6.2	7.5	8.8
COPPER, STRANDED, HARD-DRAWN							
AWG							
2–3 [1]	1.6 (*2.0*)	2.5 (*2.8*)	3.4 (*3.9*)	4.5 (*5.0*)	5.8 (*6.3*)	7.2 (*7.7*)	8.8 (*9.3*)
4–3 [1]	1.8 (*1.9*)	2.7 (*2.8*)	3.8	4.9	6.3	7.8	9.5

See footnote at end of table.

TABLE D23—*Total sag of bare conductors for various spans*—Continued

LIGHT-LOADING DISTRICT—continued

Conductor size, type, and stranding	Total sag for span lengths in feet						
	200	250	300	350	400	450	500
COPPER, SOLID, HARD-DRAWN							
AWG							
2 [1]	1.6 (*2.3*)	2.4 (*3.2*)	3.4 (*4.4*)	4.5 (*5.7*)	5.9 (*7.1*)	7.5 (*8.7*)	9.2 (*10.5*)
4 [1]	1.7 (*2.2*)	2.6 (*3.2*)	3.7 (*4.2*)	5.0 (*5.5*)	6.3 (*6.9*)	7.8 (*8.4*)	9.5 (*10.1*)
6 [1]	1.9 (*2.1*)	2.9 (*3.0*)	4.0 (*4.1*)	5.3	6.7	8.4	10.0
8 [1]	2.2	3.2	4.5	5.8	7.3	9.0	10.7
COPPERWELD-COPPER							
2 A	1.2 (*1.4*)	1.9 (*2.1*)	2.6 (*2.9*)	3.5 (*3.9*)	4.5 (*4.9*)	5.7 (*6.0*)	6.9 (*7.2*)
4 A	1.3	2.0	2.7	3.7	4.7	5.8	7.1
6 A	1.5	2.2	3.1	4.1	5.2	6.6	7.7
8 A	1.5	2.3	3.2	4.2	5.3	6.5	7.8
8 C	1.9	2.9	4.0	5.2	6.6	8.0	9.6
9½ D	1.6	2.5	3.4	4.4	5.6	6.8	8.2
COPPERWELD							
AWG							
3 No. 12	1.3	2.0	2.8	3.7	4.8	5.9	7.1
STEEL-COPPER, 3-WIRE, AMERDUCTOR SCP OR SCG							
2	1.1 (*1.2*)	1.6 (*1.8*)	2.3 (*2.5*)	3.1 (*3.4*)	4.0 (*4.3*)	5.0 (*5.3*)	6.1 (*6.4*)
4	1.1	1.7	2.4	3.2	4.1	5.1	6.2
6	1.3	1.9	2.7	3.5	4.5	5.6	6.8
8	1.4	2.1	3.0	3.9	4.9	6.1	7.3
8 X	1.3	1.9	2.7	3.6	4.6	5.7	6.9
9 X	1.3	1.9	2.7	3.6	4.6	5.8	7.0
AMERSTEEL, 3-WIRE, GALVANIZED							
BWG							
4 3S–130	0.8	1.3	1.8	2.4	3.2	3.9	4.8
6 3S–130	0.9	1.4	2.0	2.8	3.5	4.4	5.3
8 3S–130	1.1	1.7	2.4	3.2	4.1	5.1	6.2
4 3S–80	1.2	1.8	2.5	3.4	4.3	5.4	6.5
6 3S–80	1.3	2.0	2.8	3.8	4.7	5.8	7.1
8 3S–80	1.6	2.3	3.3	4.3	5.5	6.8	8.2
CRAPO, STRANDED, 3-WIRE, GALVANIZED STEEL							
BWG							
4 HTC–130	0.8	1.3	1.8	2.4	3.2	3.9	4.8
6 HTC–130	0.9	1.4	2.0	2.8	3.5	4.4	5.3
8 HTC–130	1.1	1.7	2.4	3.2	4.1	5.1	6.2
4 HTC–80	1.2	1.8	2.5	3.4	4.3	5.4	6.5
6 HTC–80	1.3	2.0	2.8	3.8	4.7	5.8	7.1
8 HTC–80	1.6	2.3	3.3	4.3	5.5	6.8	8.2
AMERSTEEL, SOLID, GALVANIZED							
BWG							
4 S–130 [1]	0.8	1.3	1.8	2.5	3.2	3.9	4.7
6 S–130 [1]	1.1	1.5	2.1	2.8	3.6	4.4	5.3
8 S–130 [1]	1.2	1.8	2.5	3.3	4.2	5.2	6.2
4 S–80 [1]	1.1 (*1.6*)	1.8 (*2.3*)	2.5 (*3.1*)	3.3 (*4.0*)	4.3 (*5.0*)	5.3 (*6.0*)	6.4 (*7.2*)
6 S–80 [1]	1.4	2.1	2.9	3.8	4.8	6.0	7.2
8 S–80 [1]	1.6	2.4	3.3	4.4	5.5	6.7	8.0

See footnote at end of table.

TABLE D23—*Total sag of bare conductors for various spans*—Continued

LIGHT-LOADING DISTRICT—Continued

Conductor size, type and stranding	Total sag for span lengths in feet						
	200	250	300	350	400	450	500
CRAPO, SOLID, GALVANIZED STEEL							
BWG							
4 HTC-130 [1]	0.8	1.3	1.8	2.5	3.2	3.9	4.7
6 HTC-130 [1]	1.1	1.5	2.1	2.8	3.6	4.4	5.3
8 HTC-130 [1]	1.2	1.8	2.5	3.3	4.2	5.2	6.2
4 HTC-80 [1]	1.1 (*1.6*)	1.8 (*2.3*)	2.5 (*3.1*)	3.3 (*4.0*)	4.3 (*5.0*)	5.3 (*6.0*)	6.4 (*7.2*)
6 HTC-80 [1]	1.4	2.1	2.9	3.8	4.8	6.0	7.2
8 HTC-80 [1]	1.6	2.4	3.3	4.4	5.5	6.7	8.0

[1] Based on maximum tension of 50 percent ultimate strength of conductors.

Appendix 2C. Catenary Curve

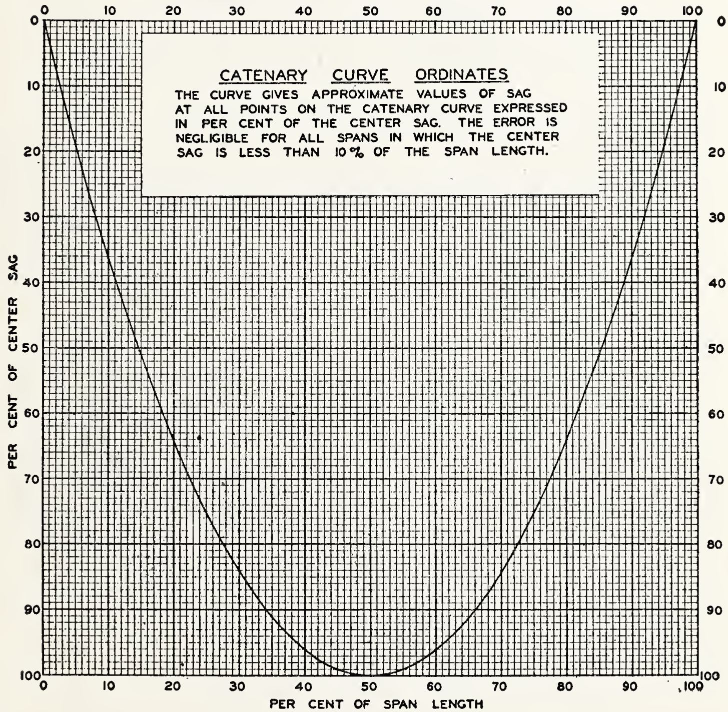


FIGURE 18.—*Catenary curve.*

APPENDIX 3. WOOD POLE DATA

This appendix contains the following:

3A. Bending moments on wood poles due to wind.

This consists of a nomograph (fig. 19) for use in obtaining the bending moment at the ground line on a wood pole due to the transverse wind pressure on that pole. As an alternate method the applicable following formula may be used:

For heavy and medium loading, $M=0.018(2T+G)H^2$.

For light loading, $M=0.04(2T+G)H^2$.

where

M = the bending moment, in pound-feet,
T = the top circumference, in inches,
G = the ground-line circumference, in inches,
H = the height of pole above ground, in feet.

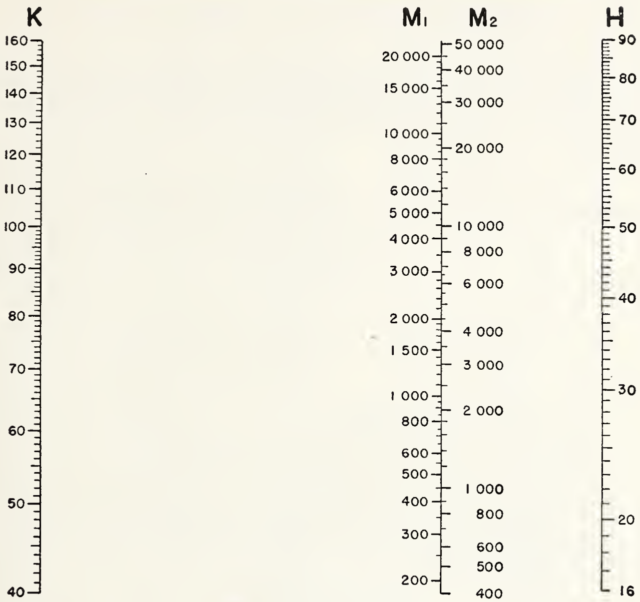
3B. Ultimate resisting moments of wood poles.

This contains curves (fig. 20) for use in determining directly the ultimate resisting moments corresponding to the ground-line circumferences for eight species of wood-pole timber. There is also included a discussion and an example of the use of these curves in determining the ground-line circumference of the pole required for an assumed situation.

3C. Dimensions of wood poles.

Tables D24 to D29, inclusive, give the top and 6-feet-from-butt circumferences of poles of classes 1 to 7, inclusive, of those species of wood-pole timber for which standards have been approved by the American Standards Association (05.1–1941 to 05.6–1941; sponsor, ASA Telephone Group). Top circumferences only are given for poles of classes 8, 9, and 10 of those standards.

Appendix 3A. Pole Bending Moments



$K = 2T + G$ WHERE T = CIRCUMFERENCE AT POLE TOP, IN INCHES.
AND G = CIRCUMFERENCE AT GROUND LINE, IN INCHES.

H = HEIGHT OF POLE ABOVE GROUND LINE, IN FEET.

M_1 = MOMENT AT GROUND LINE FOR HEAVY AND MEDIUM LOADING, IN POUND-FEET.

M_2 = MOMENT AT GROUND LINE FOR LIGHT LOADING, IN POUND-FEET.

LAY STRAIGHTEDGE ACROSS CHART FROM K TO H AND READ BENDING MOMENT AT M_1 OR M_2

FIGURE 19.—*Bending moment due to wind pressure on pole.*

Appendix 3B. Resisting Moments of Wood Poles

The accompanying chart (fig. 20) gives ultimate resisting moments corresponding to various circumferences of poles of different kinds of timber. By using these curves, required circumferences for any percentage of ultimate stress may be determined at any pole section, although usually only the ground-line section and the section at the point of guy attachment are of interest.

The curves are based on ultimate fiber stresses* for various commonly used species of pole timber as follows:

Curve	Kind of wood	Ultimate fiber stress
		lb/in.^{2}
1	Creosoted southern pine and Douglas fir	7, 400
2	Lodgepole pine	6, 600
3	Chestnut	6, 000
4	Western red cedar	5, 600
5	Cypress	5, 000
6	Northern white cedar and redwood	3, 600

The following formula was used in determining the relationships between the pole circumferences and resisting moments on the chart:

$$M=0.000264fC^3$$

where

M=resisting moment of wood pole, in pound-feet.
f=ultimate fiber stress of pole timber, in pounds per square inch.
C=pole circumference at center of moments (ground line, point of guy attachment, etc.) in inches.

*These ultimate fiber stresses have been adopted as standard by the American Standards Association (05a—1933), except in the case of cypress and redwood. Values for these two species are the same as those contained in previous editions of the NESC and are somewhat below the values given for small clear specimens in tables published by the Forest Products Laboratory.

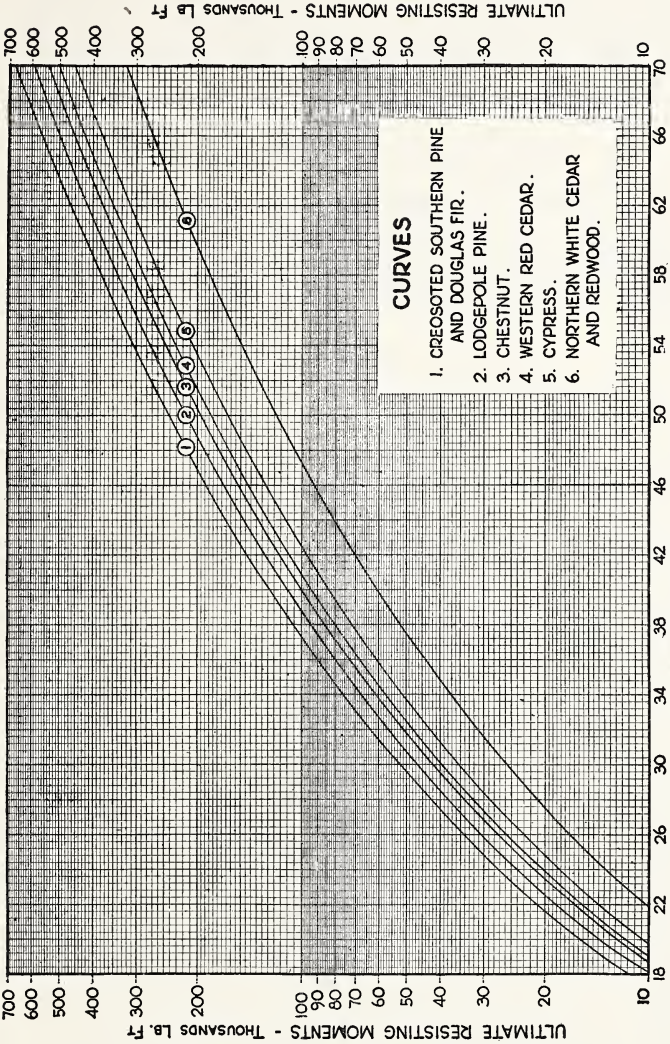


Figure 20.—*Ultimate resisting moments of wood poles.*

EXAMPLE

Given: An unguyed 40-ft creosoted southern pine pole at a grade B crossing with a transverse load of 1,000 lb applied 32 ft above ground (assumed center of load) and the allowable percentage of ultimate fiber stress limited to 25 percent in accordance with table 20 of rule 261, A,4(d).

To determine: The class of pole required for this situation.

Computations:

$$\text{Bending moment} = 1{,}000 \times 32 = 32{,}000 \text{ lb-ft.}$$

$$\text{Required resisting moment} = 32{,}000/.25 = 128{,}000 \text{ lb-ft.}$$

From curve 1 (fig. 20) the corresponding required ground-line circumference is 40.4 inches. The class of pole, as determined by table D24, Appendix 3C, corresponding to this height and circumference is class 1.

TABLE D24.—*American Standard dimensions for creosoted southern pine poles*

Class		1	2	3	4	5	6	7	8	9	10
Minimum top circumference (inches)		27	25	23	21	19	17	15	18	15	12
Length of pole	Ground-line distance from butt [1]	Minimum circumference at 6 feet from butt									
ft	*ft*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*			
16	3½					21.5	19.5	18.0	(2)	(2)	(2)
18	3½			26.5	24.5	22.5	21.0	19.0			
20	4	31.5	29.5	27.5	25.5	23.5	22.0	20.0			
22	4	33.0	31.0	29.0	26.5	24.5	23.0	21.0			
25	5	34.5	32.5	30.0	28.0	26.0	24.0	22.0			
30	5½	37.5	35.0	32.5	30.0	28.0	26.0	24.0			
35	6	40.0	37.5	35.0	32.0	30.0	27.5	25.5			
40	6	42.0	39.5	37.0	34.0	31.5	29.0	27.0			
45	6½	44.0	41.5	38.5	36.0	33.0	30.5	28.5			
50	7	46.0	43.0	40.0	37.5	34.5	32.0	29.5			
55	7½	47.5	44.5	41.5	39.0	36.0	33.5				
60	8	49.5	46.0	43.0	40.0	37.0	34.5				
65	8½	51.0	47.5	44.5	41.5	38.5					
70	9	52.5	49.0	46.0	42.5	39.5					
75	9½	54.0	50.5	47.0	44.0						
80	10	55.0	51.5	48.5	45.0						
85	10½	56.5	53.0	49.5							
90	11	57.5	54.0	50.5							

[1] The figures in this column are intended solely for use whenever a definition of ground line is necessary in order to apply specification requirements relating to scars, straightness, etc.
[2] No butt requirement.

TABLE D25.—*American Standard dimensions for western red cedar poles*

Class		1	2	3	4	5	6	7	8	9	10
Minimum top circumference (inches)		27	25	23	21	19	17	15	18	15	12
Length of pole	Ground-line distance from butt [1]	Minimum circumference at 6 feet from butt									
ft	*ft*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*			
16	3½	------	------	------	------	23.0	21.5	19.5	(2)	(2)	(2)
18	3½	------	------	28.5	26.5	24.5	22.5	21.0			
20	4	34.5	32.0	30.0	28.0	25.5	23.5	22.0			
22	4	36.0	33.5	31.5	29.0	27.0	25.0	23.0			
25	5	38.0	35.5	33.0	30.5	28.5	26.0	24.5			
30	5½	41.0	38.5	35.5	33.0	30.5	28.5	26.5			
35	6	43.5	41.0	38.0	35.5	32.5	30.5	28.0			
40	6	46.0	43.5	40.5	37.5	34.5	32.0				
45	6½	48.5	45.5	42.5	39.5	36.5					
50	7	50.5	47.5	44.5	41.0	38.0					
55	7½	52.5	49.5	46.0	42.5	39.5					
60	8	54.5	51.0	47.5	44.0						
65	8½	56.0	52.5	49.0	45.5						
70	9	57.5	54.0	50.5	47.0						
75	9½	59.5	55.5	52.0	48.5						
80	10	61.0	57.0	53.5	49.5						
85	10½	62.5	58.5	54.5							
90	11	63.5	60.0	56.0							

[1] See footnote to table D24.
[2] No butt requirement.

TABLE D26.—*American Standard dimensions for chestnut poles*

Class		1	2	3	4	5	6	7	8	9	10
Minimum top circumference (inches)		27	25	23	21	19	17	15	18	15	12
Length of pole	Ground-line distance from butt [1]	Minimum circumference at 6 feet from butt									
ft	*ft*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	(2)	(2)	(2)
16	3½	----	----	----	----	22.5	21.0	19.5			
18	3½	----	----	28.0	26.0	24.0	22.0	20.5			
20	4	33.5	31.5	29.5	27.0	25.0	23.0	21.5			
22	4	35.0	33.0	30.5	28.5	26.5	24.5	22.5			
25	5	37.0	34.5	32.5	30.0	28.0	25.5	24.0			
30	5½	40.0	37.5	35.0	32.5	30.0	28.0	26.0			
35	6	42.5	40.0	37.5	34.5	32.0	30.0	27.5			
40	6	45.0	42.5	39.5	36.5	34.0	31.5	29.5			
45	6½	47.5	44.5	41.5	38.5	36.0	33.0	31.0			
50	7	49.5	46.5	43.5	40.0	37.5	34.5	32.0			
55	7½	51.5	48.5	45.0	42.0	39.0	36.0	----			
60	8	53.5	50.0	46.5	43.5	----	----	----			
65	8½	55.0	51.5	48.0	45.0	----	----	----			
70	9	56.5	53.0	----	----	----	----	----			

[1] See footnote to table D24.
[2] No butt requirement.

TABLE D27.—*American Standard dimensions for northern white cedar poles*

Class		1	2	3	4	5	6	7	8	9	10
Minimum top circumference (inches)		27	25	23	21	19	17	15	18	15	12
Length of pole	Ground-line distance from butt [1]	Minimum circumference at 6 feet from butt									
ft	*ft*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*			
16	3½					26.0	24.0	22.0	(2)	(2)	(2)
18	3½			32.5	30.0	28.0	25.5	23.5			
20	4	39.5	37.0	34.0	31.5	29.0	27.0	25.0			
22	4	41.0	38.5	36.0	33.0	30.5	28.0	26.0			
25	5	43.5	41.0	38.0	35.5	32.5	30.0	28.0			
30	5½	47.5	44.5	41.5	38.5	35.5	33.0	30.5			
35	6	50.5	47.5	44.0	41.0	38.0	35.0	32.5			
40	6	53.5	50.0	46.5	43.5	40.0	37.0				
45	6½	56.0	52.5	49.0	45.5	42.0					
50	7	58.5	55.0	51.5	47.5	44.0					
55	7½	61.0	57.5	53.5	49.5	46.0					
60	8	63.5	59.5	55.5	51.5						

[1] See footnote to table D24.
[2] No butt requirement.

Table D28.—*American Standard dimensions for creosoted Douglas fir poles*

Class		1	2	3	4	5	6	7	8	9	10
Minimum top circumference (inches)		27	25	23	21	19	17	15	18	15	12
Length of pole	Ground-line distance from butt [1]	Minimum circumference at 6 feet from butt									
ft	*ft*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*			
16	3½					21.5	19.5	18.0	(2)	(2)	(2)
18	3½			26.5	24.5	22.5	21.0	19.0			
20	4	31.5	29.5	27.5	25.5	23.5	22.0	20.0			
22	4	33.0	31.0	29.0	26.5	24.5	23.0	21.0			
25	5	34.5	32.5	30.0	28.0	26.0	24.0	22.0			
30	5½	37.5	35.0	32.5	30.0	28.0	26.0	24.0			
35	6	40.0	37.5	35.0	32.0	30.0	27.5	25.5			
40	6	42.0	39.5	37.0	34.0	31.5	29.0	27.0			
45	6½	44.0	41.5	38.5	36.0	33.0	30.5	28.5			
50	7	46.0	43.0	40.0	37.5	34.5	32.0	29.5			
55	7½	47.5	44.5	41.5	39.0	36.0	33.5				
60	8	49.5	46.0	43.0	40.0	37.0	34.5				
65	8½	51.0	47.5	44.5	41.5	38.5					
70	9	52.5	49.0	46.0	42.5	39.5					
75	9½	54.0	50.5	47.0	44.0						
80	10	55.0	51.5	48.5	45.0						
85	10½	56.5	53.0	49.5							
90	11	57.5	54.0	50.5							

[1] See footnote to table D24.
[2] No butt requirement

TABLE D29.—*American Standard dimensions for lodgepole pine poles*

Class		1	2	3	4	5	6	7	8	9	10
Minimum top circumference (inches)		27	25	23	21	19	17	15	18	15	12
Length of pole	Ground-line distance from butt [1]	Minimum circumference at 6 feet from butt									
ft	*ft*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*			
16	3½					22.0	20.5	19.0	[2]	[2]	[2]
18	3½			27.5	25.5	23.5	21.5	20.0			
20	4	32.5	30.5	28.5	26.5	24.5	22.5	21.0			
22	4	34.0	32.0	30.0	27.5	25.5	23.5	22.0			
25	5	36.0	33.5	31.0	29.0	27.0	25.0	23.0			
30	5½	39.0	36.5	34.0	31.5	29.0	27.0	25.0			
35	6	41.5	38.5	36.0	33.5	31.0	28.5	26.5			
40	6	44.0	41.0	38.0	35.5	33.0	30.5	28.0			
45	6½	46.0	43.0	40.0	37.0	34.5	32.0	29.5			
50	7	48.0	45.0	42.0	39.0	36.0	33.5	31.0			
55	7½	49.5	46.5	43.5	40.5	37.5	34.5				
60	8	51.5	48.0	45.0	42.0	38.5					
65	8½	53.0	49.5	46.0	43.0						
70	9	54.5	51.0	47.5							
75	9½	56.0	52.5								

[1] See footnote to table D24.
[2] No butt requirement.

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