U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

DISCUSSION OF THE NATIONAL ELECTRICAL SAFETY CODE

Part 2 and Grounding Rules

NATIONAL BUREAU OF STANDARDS HANDBOOK H39

U. S. DEPARTMENT OF COMMERCE
JESSE H. JONES, Secretary
NATIONAL BUREAU OF STANDARDS
LYMAN J. BRIGGS, Director

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DISCUSSION OF THE NATIONAL ELECTRICAL SAFETY CODE

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[Issued July 15, 1944]

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1944

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 75c

PREFACE

Because of the inherent need for conciseness in the code itself, previous editions of the National Electrical Safety Code have been accompanied by a separately printed discussion of these rules. The value of such discussions has been proved by the widespread demand for them.

As a war conservation measure, the publication of the complete fifth edition of the National Electrical Safety Code as a single volume has been deferred. However, the six constituent parts are available as separate Handbooks (National Bureau of Standards Handbooks H31 to H36, inclusive). The discussions will be handled similarly, and this Handbook, covering Part 2 (Handbook 32) is the first of this series to be issued. The considerable amount of supplementary data it contains and the technical nature of Part 2 itself make this discussion the most important of the group and consequently the first to appear.

The fifth edition of Part 2, approved by the American Standards Association on August 27, 1941, as an American Standard, differs considerably in many of its requirements from the earlier editions. This present discussion covers the more important of these revised requirements, as well as others which, though substantially unchanged, can be effectively supplemented by a discussion. Many of the rules in the code are not discussed because their intent and the reasons for their inclusion are evident.

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.

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.

Lyman J. Briggs, *Director.*

NATIONAL BUREAU OF STANDARDS ADVISORY COMMITTEE FOR THE PREPARATION OF THE DISCUSSION HANDBOOK

J. A. Dickinson,[1] chairman	National Bureau of Standards.
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G. Charlesworth [2]	Iowa State Commerce Commission.
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K. H. Gordon	Pennsylvania Railroad Co.
J. W. Hines	American Telephone & Telegraph Co.
J. T. Binford (alternate).	
D. H. Mackay [4]	Rural Electrification Administration.
B. C. Sherwood	Association of Edison Illuminating Companies.

[1] Replaced M. G. Lloyd, deceased.

[2] Replaced original appointee, P. L. Holland, Maryland Public Service Commission, who was unable to serve.

[3] Now on active duty with military forces—Orris McGinnis, acting.

[4] Replaced original appointee, J. K. O'Shaughnessy, REA.

NATIONAL ELECTRICAL SAFETY CODE

Part 1, Safety rules for the installation and maintenance of electrical supply stations, H31 (10c).
Part 2, Safety rules for the installation and maintenance of electric supply and communication lines, H32 (65c).
Part 3, Safety rules for the installation and maintenance of electric utilization equipment, H33 (15c).
Part 4, Safety rules for the operation of electric equipment and lines, H34 (10c).
Part 5, Safety rules for radio installations, H35 (10c).
Part 6, Safety rules for electric fences, H36 (5c).

The separate parts listed above may be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at the prices stated.

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TABLES

DISCUSSION OF THE NATIONAL ELECTRICAL SAFETY CODE, PART 2 AND GROUNDING RULES

DISCUSSION OF SECTION 9—RULES COVERING METHODS OF PROTECTIVE GROUNDING OF OVERHEAD AND UNDERGROUND LINES AND RELATED EQUIPMENT

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 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

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 experience 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

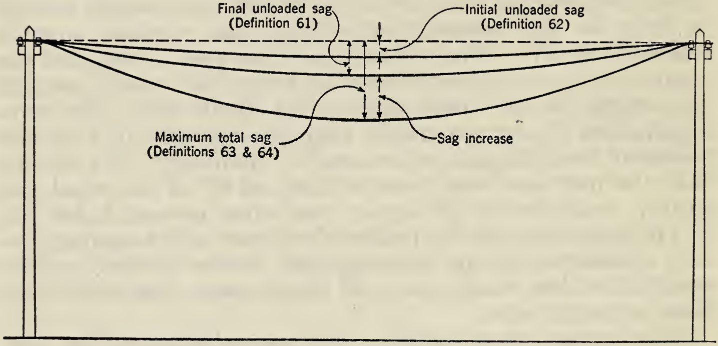

FIGURE 1.—*Sags.*

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

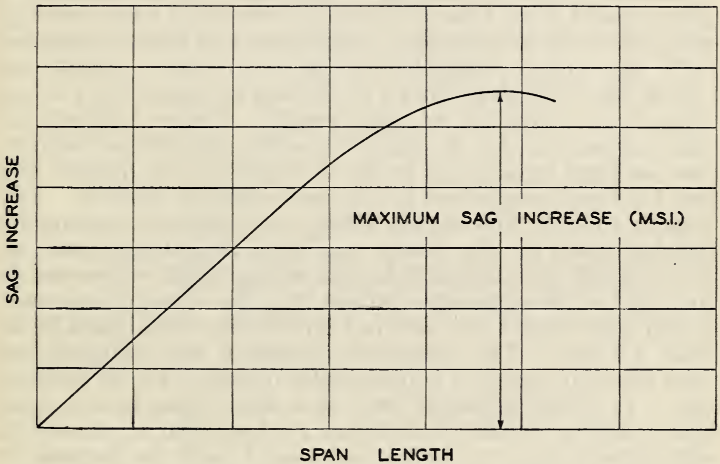

FIGURE 2.—*Typical sag-increase curve.*

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.

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,

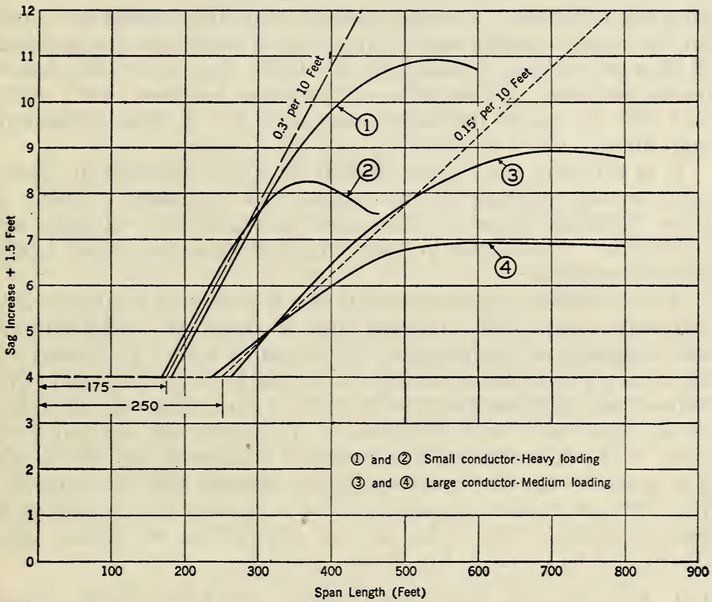

FIGURE 3.—*Relation between sag increases and clearance increments.*

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

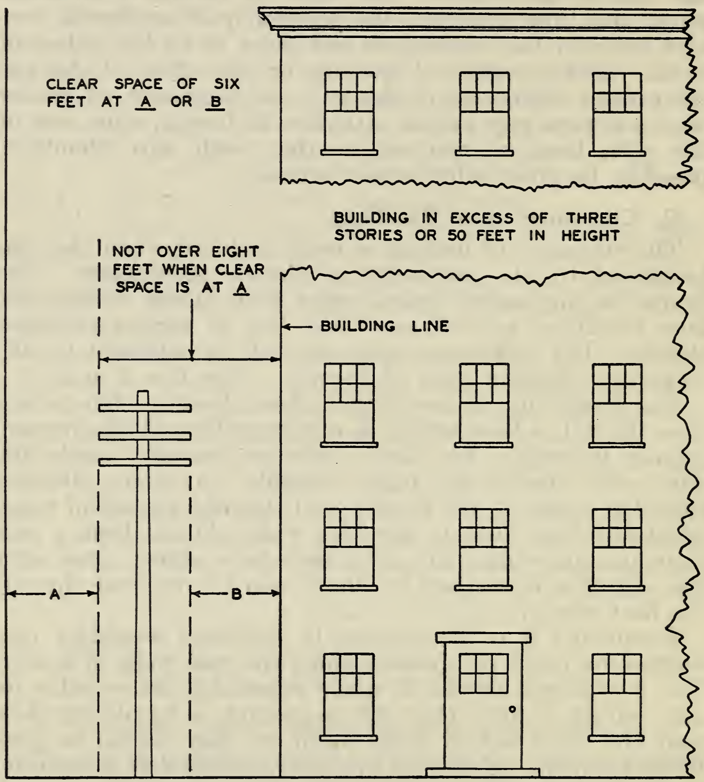

FIGURE 4.—*Clearances of conductors from buildings to provide fire-ladder space.*

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,

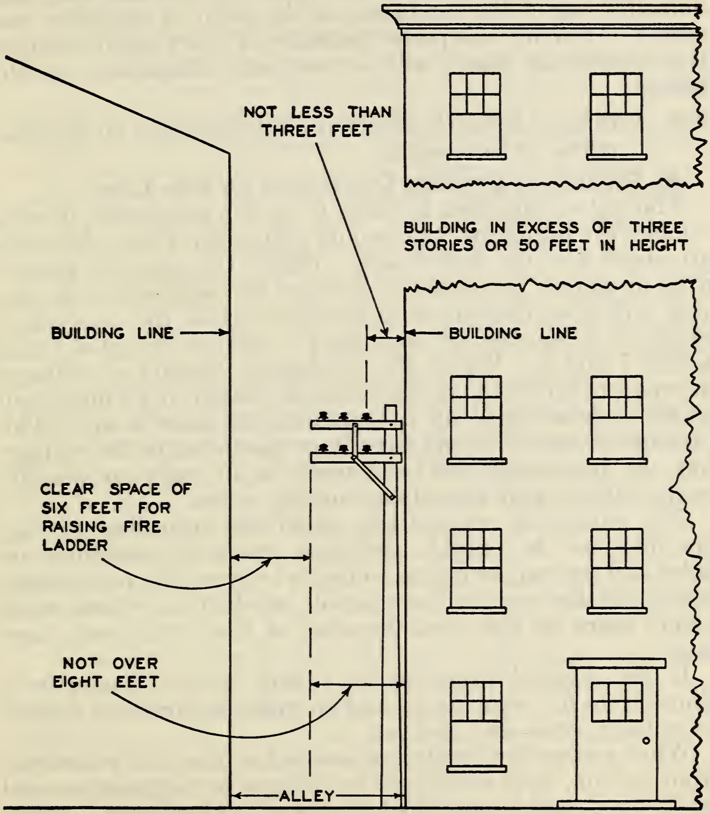

Figure 5.—*Clearances of conductors from buildings to provide fire-ladder space.*

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

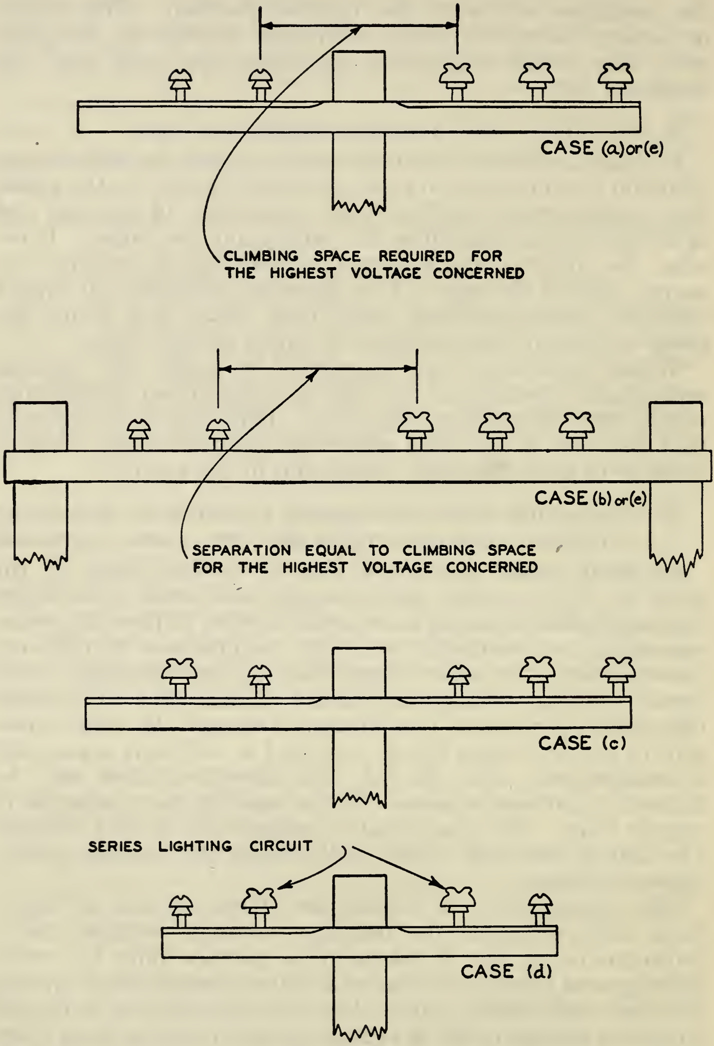

FIGURE 6.—*Permissible arrangements of supply circuits of different consecutive voltage classifications on the same crossarm.*

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.

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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

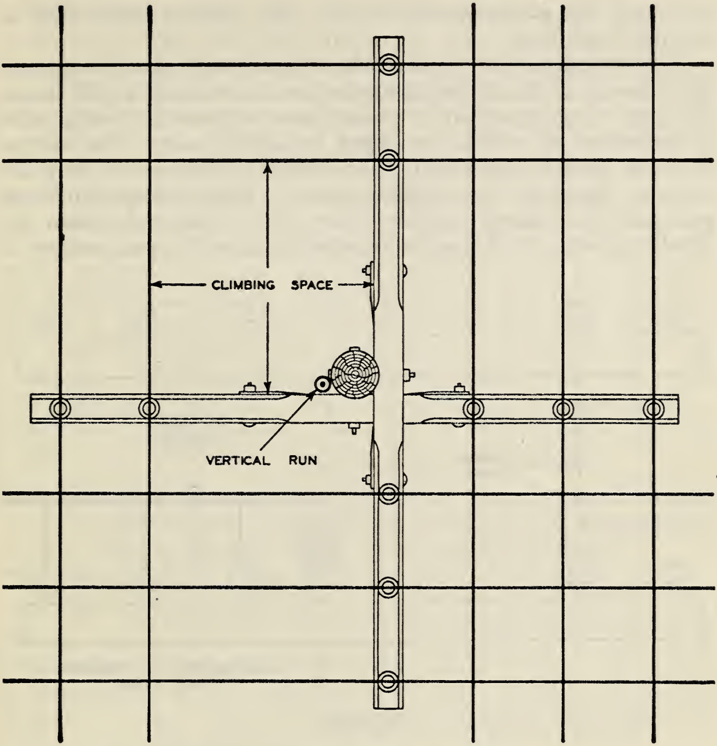

FIGURE 7.—*Example of unobstructed climbing space.*

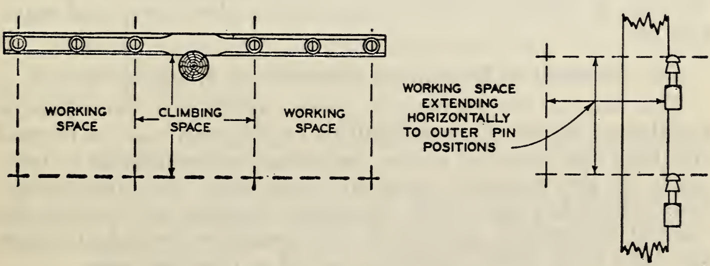

FIGURE 8.—*Working space.*

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

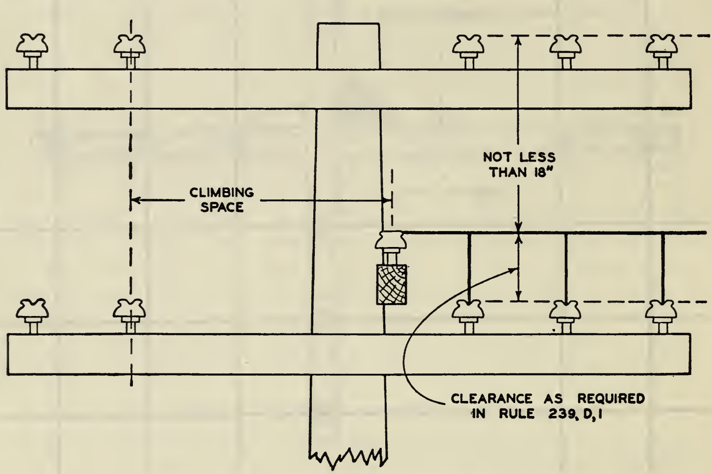

Figure 9.—*Obstruction of working space by buckarm.*

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-

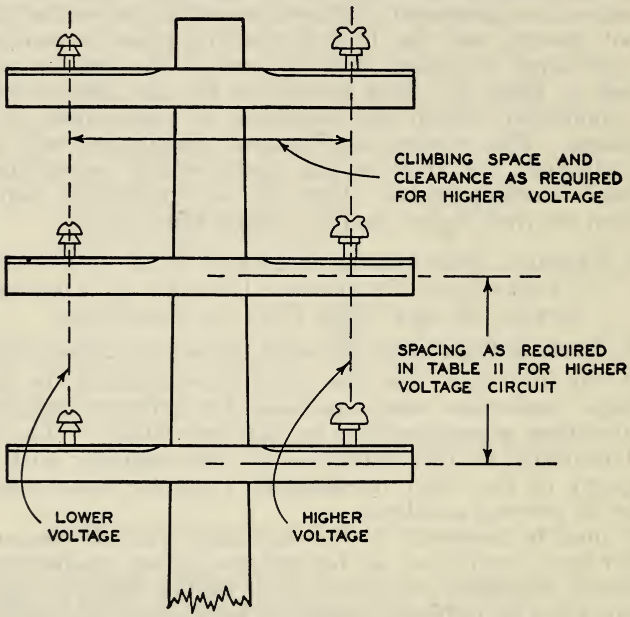

Figure 10.—*Vertical arrangement of circuits.*

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.

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

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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

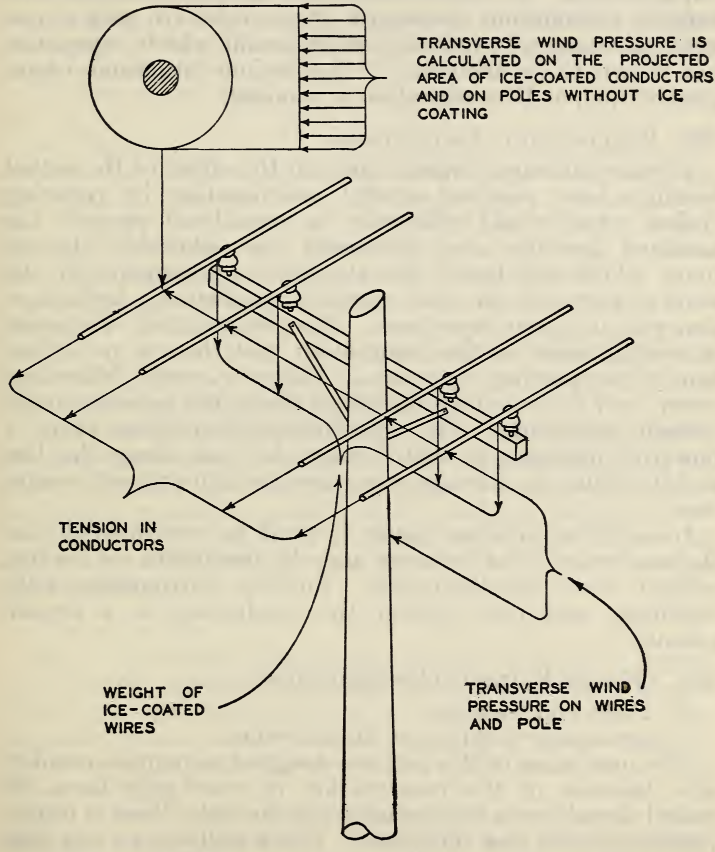


FIGURE 11.—*Forces producing load on supporting structures.*

"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

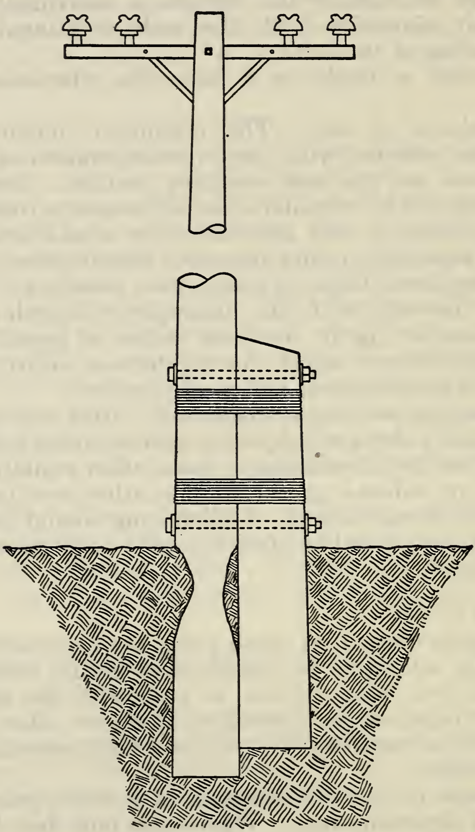


FIGURE 12.—*One method of stubbing to reinforce a deteriorated pole.*

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 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.

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.

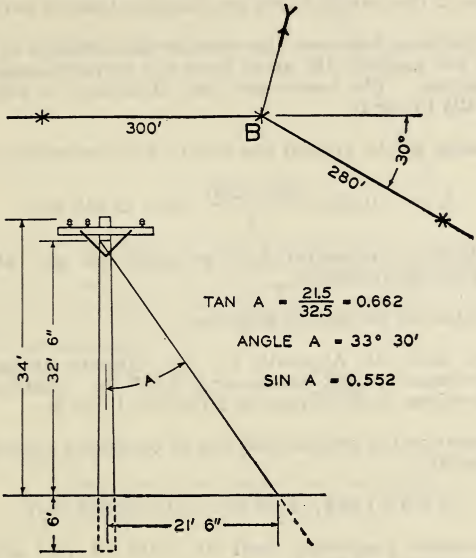
On account of the great flexibility of wood poles they may deflect considerably before developing much resistance to the transverse loads applied. Guys when installed properly are under initial stress and would fail before stretching enough to put much load on the poles. Thus, it is seen that the strength 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

$=.018\ (2T+G)\ H^2$

$=.018\ (2\times21+34)\ 34^2=1{,}580$ 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

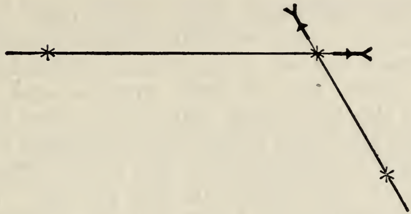
According to rule 261,C,5(a), the guy must withstand the total load without exceeding 66.7 percent of its ultimate strength, or in other words, the guy must withstand 100/66.7=1.5 times the total load without exceeding its minimum breaking strength.

Minimum breaking strength of guy

$$=\frac{\text{Total horizontal load}\times 1.5}{\sin a}=3{,}494/0.552\times 1.5=9{,}495 \text{ lb.}$$

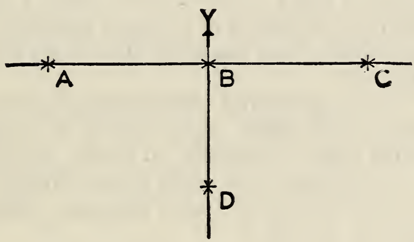
See table D10, Appendix 1A, for minimum breaking strength of guy strands.

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.

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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

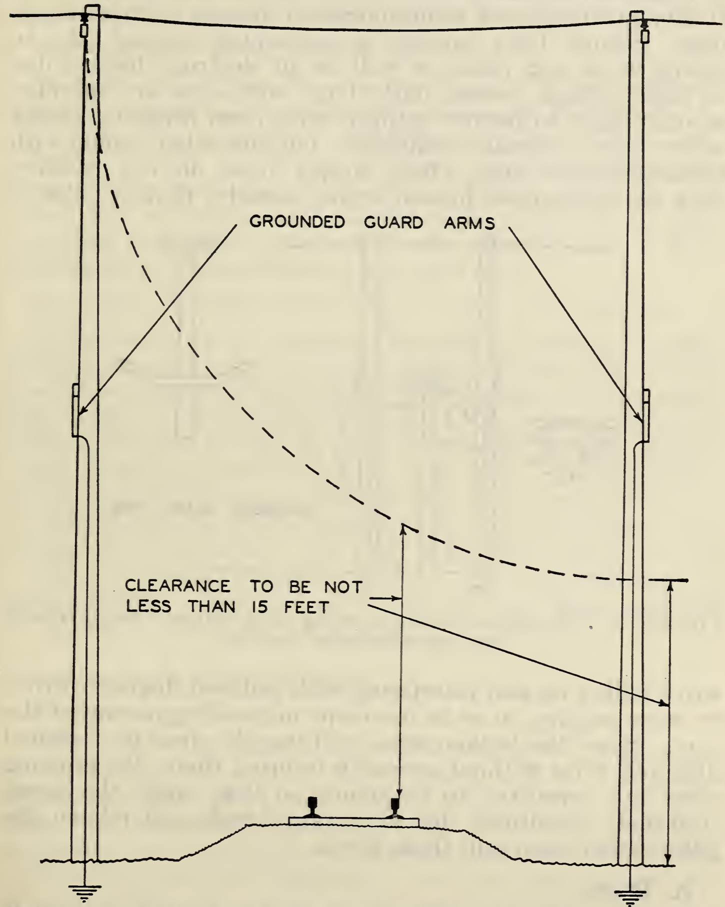

Figure 13.—*Special short-span crossing construction—supply lines over railways.*

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

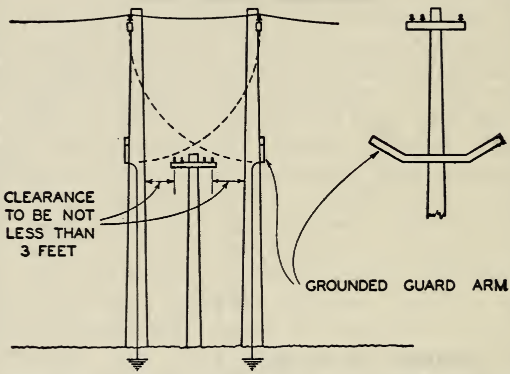

FIGURE 14.—*Special short-span crossing construction—supply circuits over communication circuits.*

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 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

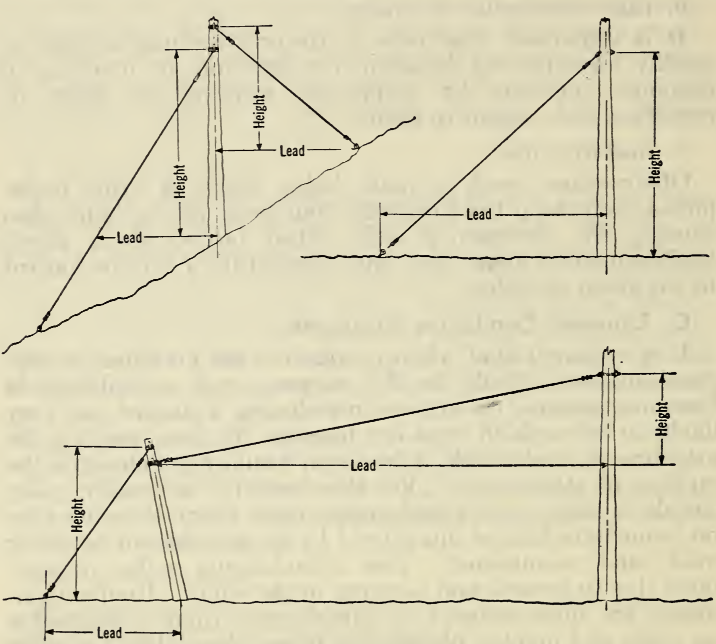

FIGURE 15.—*Lead and height of guys.*

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

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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.

Metallurgy

Guillet, Léon, 1873–

... Les étapes de la métallurgie, par Léon Guillet ... Paris, Presses universitaires de France, 1942.

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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 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 duce 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.

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.

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.

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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.

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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			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*
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
	6A/1St	.223	.0303	1,460	.0457	.1673	.2234	.1928	.2410	.5286	.4954	.4077	.9516
	6A/1St	.198	.0240	1,170	.0362	.1485	.2029	.1755	.2327	.5115	.4704	.3993	.9270

See footnotes at end of table.

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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	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 ductor 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*
7	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 thi scolumn 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 1/0F, 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			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	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*

Con-ductor size	Strand-ing	Over-all diam-eter	Cross-sec-tional area	Ultimate strength [1]					Linear loading of conductor								
									Light loading			Medium loading			Heavy loading		
				Util-ities grade	Com-mon grade	Sie-mens-Martin grade	High-strength grade	Extra-high-strength grade	Vertical (weight of con-ductor without ice)	Trans-verse (9-lb wind per sq ft on con-ductor without ice	Con-ductor load-ing [2]	Ver-tical (con-ductor plus ¼ in. of radial ice)	Trans-verse 4-lb wind per sq ft on ice covered con-ductor	Con-ductor load-ing [2]	Ver-tical (con-ductor plus ½ in. of radial ice)	Trans-verse (4-lb wind per sq ft on ice covered con-ductor	Con-ductor load-ing [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.

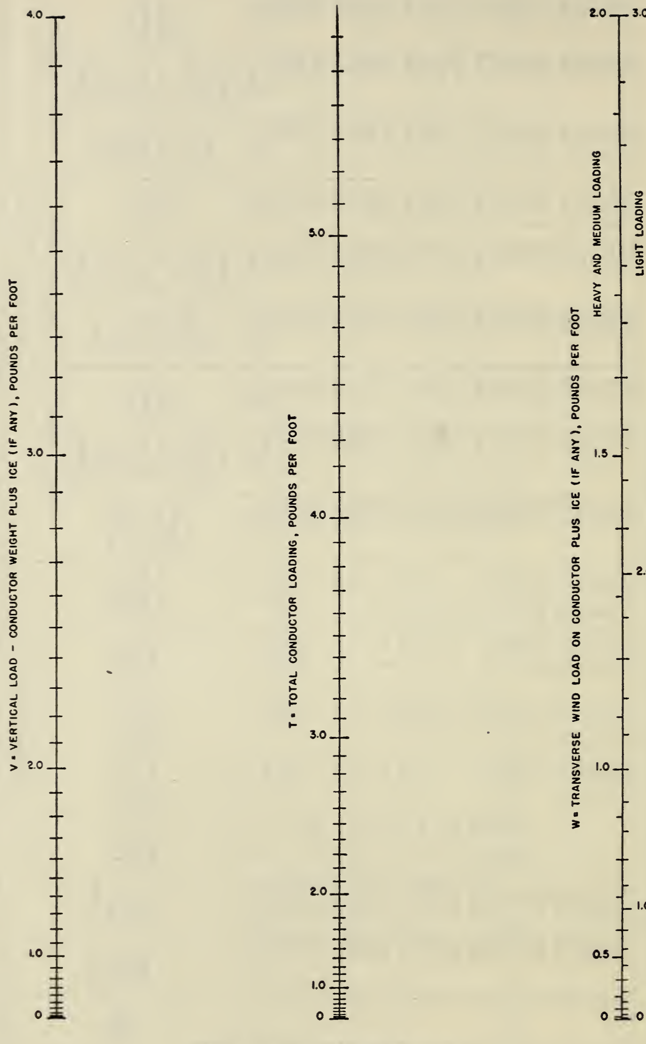


FIGURE 16.—*Conductor loading nomograph, vertical, transverse, and conductor loads—pounds per linear foot of conductor*

[See also comments on p. 99 regarding light loading.]

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
Aluminum Cable Steel Reinforced:	*lb/in.*^{2}	*lb/in.*^{2}	
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

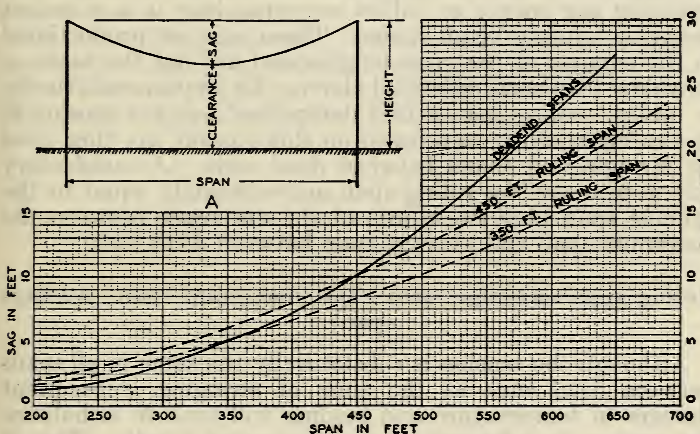


Figure 17.—*Ruling spans.*

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:

$$\text{Ruling span} = \text{average span} + 2/3\ (\text{maximum span} - \text{average span}).$$

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.

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

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*
4-HTC-130	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
	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
4-HTC-80	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
	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
6-HTC-130	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-HTC-80	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
	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
8-HTC-130	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
	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
8-HTC-80	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
	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

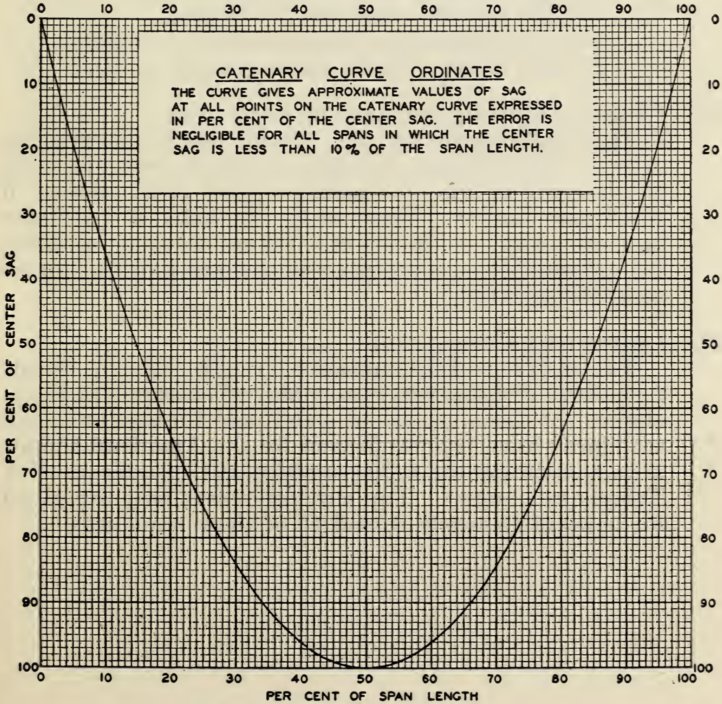


FIGURE 18.—*Catenary curve.*

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.

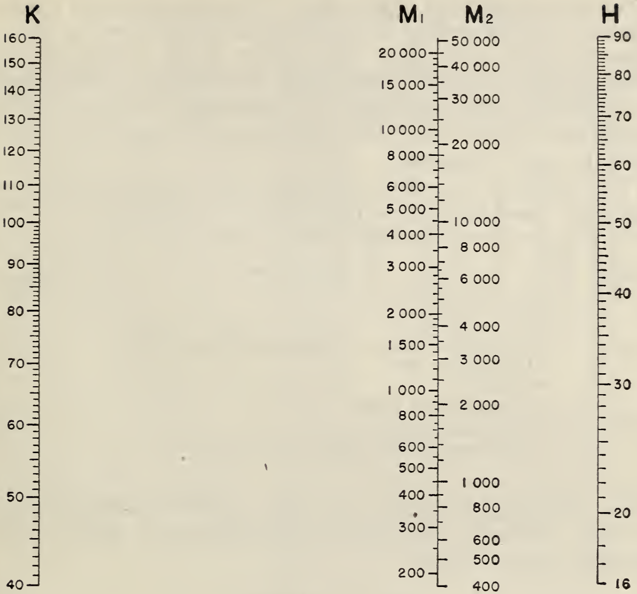
3B. Ultimate resisting moments of wood poles.

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:

$$M = 0.000264 f C^3$$

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.

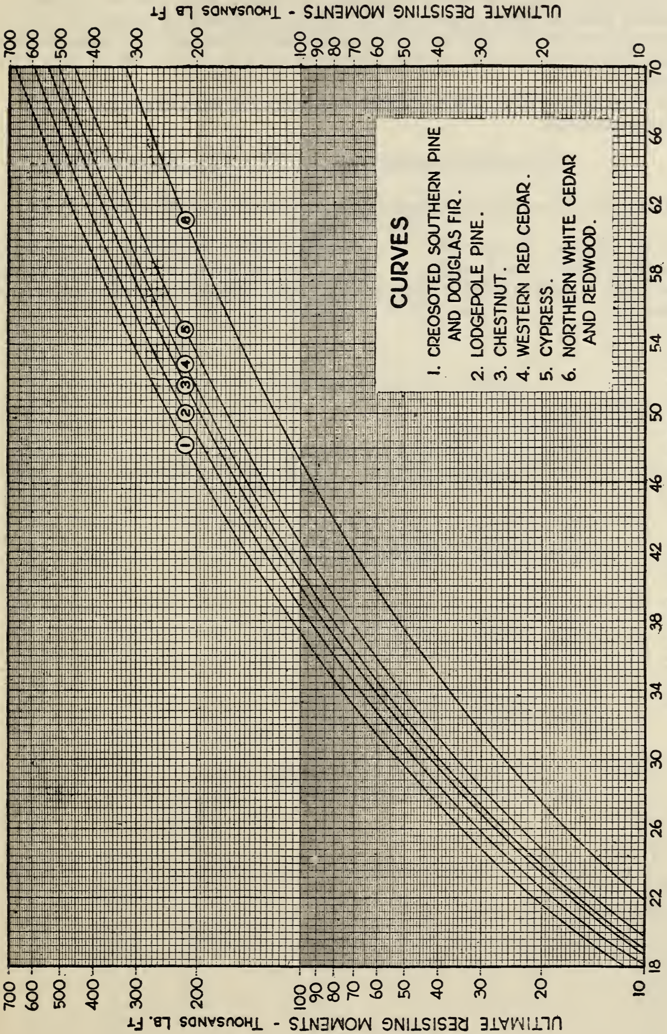


FIGURE 20.—*Ultimate resisting moments of wood poles.*

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.