Chapter E 161

LIGHTNING PROTECTION FOR ORDINARY BUILDINGS

Note: E 161.01 to E 161.04, inclusive, hereunder apply more particularly to buildings of the ordinary types which have roofs of slate, tile, or other non-conducting material. Section E 161.05 sets forth modification to the rules preceding it which may be made for the case of buildings which are roofed, or roofed and clad, with metal. Grounding and interconnection of metals are included in sections E 161.06 to E 161.08, while chapter E 162 is to be referred to when buildings are equipped with spires, steeples, flag poles or towers.

E 161.01 Conductors. (1) MATERIALS. The materials of which protective systems are made shall be relatively resistant to corrosion or shall be acceptably protected against corrosion. No combination of materials shall be used that forms an electrolytic couple of such nature that in the presence of moisture corrosion is accelerated, but where moisture is permanently excluded from the junction of such metals contact between them is not objectionable.

(a) The following list of materials comprises those commonly used for protective systems, or parts of protective systems, and with their accompanying specifications constitute materials to be regarded as standard for the purposes of this rule.

1. *Copper.* Where copper is used it shall be of the grade ordinarily required for commercial electrical work, generally designated as being of 98% conductivity when annealed.

2. *Alloys.* Where alloys of metals are used they shall be substantially as resistant to corrosion as copper under similar conditions.

3. *Copper-clad steel.* Where copper-clad steel is used, the copper covering shall be permanently and effectively welded to the steel core, and the proportion of copper shall be such that the conductance is not less than 30% of the conductance of an equivalent cross-section of solid copper.

4. *Galvanized steel.* Where steel is used it shall be thoroughly protected against corrosion by a zinc coating which will satisfactorily withstand a standard test for galvanized coatings.

Note: The importance of resistance to corrosion of lightning-conductor materials should be emphasized at this point because corrosion, either soil or atmospheric, leads to deterioration and consequent impairment of the initial degree of reliability of a system and should be forestalled wherever possible. In this connection, there are several combinations of metals, and alloys of metals, that do not lead to marked corrosion when placed in contact in the presence of moisture, whereas others do, and while it is not practicable to give here a list of such combinations, manufacturers and purchasers of lightning conductors are cautioned to use only those that have been shown by experience or adequate tests to be free from objectionable features. It may also be pointed out that atmospheric conditions in certain sea-coast sections of the United States, notably the South Atlantic and Gulf coasts, are known to be destructive to galvanized steel, and in such regions galvanized steel should be used with caution, a preference being given to copper. Copper is also to be preferred where corrosive gases are encountered, but it needs to be reinforced with a lead covering under exceptional conditions, such as are found near the tops of smokestacks. (See section E 164.02 (5).)

5. *Aluminum.* Where aluminum is used, care should be taken not to use it in contact with the ground or elsewhere where it will rapidly deteriorate, and precautions should be observed at connections with dissimilar metals. Cable conductors shall be of electrical conductor grade aluminum.

(2) FORM AND SIZE. (a) The following sub-sections give minimum sizes and weights for main and branch conductors. Conductors used for bonding and inter-connecting metallic bodies to the main cable, and which will not normally be required to carry the main lightning current, may be reduced in size.

(b) Conductors for inter-connection to domestic water systems, steam or hot water heating systems, or other metallic masses having a low resistance to ground shall be full size, since in the event of a direct stroke the major portion of the discharge current may flow to ground over such a system.

1. *Copper cable.* Copper cable conductors shall weigh not less than 187.5 lb. per M ft. The size of any wire of a cable shall be not less than No. 17 AWG (0.045 inch).

2. *Copper tube, copper solid section and copper-clad steel.* Tube, or solid section conductors of copper or copper-clad steel shall weigh not less than 187.5 lb. per M ft. The thickness of any tube wall shall be not less than No. 20 AWG (0.032 inch). The thickness of any copper ribbon or strip shall be not less than No. 16 AWG (0.051 inch).

3. *Galvanized-steel.* Galvanized-steel conductors shall have a net weight of steel of not less than 320 lb. per M ft. and a zinc coating of not less than 2 ounces per square foot of galvanized surface. The thickness of any tube wall, web or ribbon before galvanizing shall be not less than No. 17, U. S. Standard Sheet Gage (0.056 inch) and the diameter of any wire of a cable before galvanizing shall be not less than No. 14 Steel Wire Gage (0.080 inch).

4. *Aluminum.* a. Aluminum cable conductors shall weigh not less than 95 pounds per thousand feet and the size of any wire of the cable shall be not less than No. 14 AWG (0.064 inch). Aluminum conductors for bonding and interconnecting metallic bodies to the main cable shall be at least the equivalent in strength and cross-sectional area of a No. 4 AWG (0.204 inch) aluminum wire. Aluminum strip conductors for interconnecting metallic bodies to the main conductor cable, if void of perforations, shall be not less than No. 14 AWG (0.064 inch) in thickness and at least ½ inch wide. If perforated, the strip shall be as much wider as the diameter of the perforations. Aluminum strip for connecting exposed water pipes shall be not less than No. 12 AWG (0.080 inch) in thickness and at least 1½ inch wide.

b. Aluminum connectors shall be not less than No. 12 AWG (0.080 inch) in thickness and of the same design and dimensions required for stamped copper connectors.

c. Aluminum tubular points shall be not less than ⅝ inch O.D., No. 16 AWG (0.050 inch) wall thickness and of the same lengths as required for copper points. Solid aluminum points shall be not less than ½ inch in diameter and of the same lengths as required for copper points.

d. Aluminum air terminal supports (for points and elevation rods), when stamped, shall be not less than No. 14 AWG (0.064 inch) in thickness and of the same design and dimensions required for copper supports.

e. Cast aluminum parts (fasteners, clamps, connectors, fixtures, etc.), shall be of the same designs and dimensions required for copper alloy fittings and equivalent in strength and conductivity.

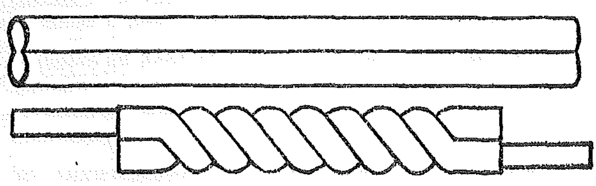
f. Copper, copper-covered and copper alloy fixtures and fittings shall not be used for the installation of aluminum lightning protection systems. Aluminum, galvanized iron or aluminum alloy fixtures and fittings are the only types permitted, except for ground connections as provided in the next paragraph.

Note: The use of aluminum materials for direct grounding of aluminum systems of lightning protection is not acceptable and they should never be buried in earth. Galvanized iron ground rods, leads and clamps are satisfactory for grounding aluminum systems. Copper or copper-covered ground rods and leads may be employed, provided the clamps for connecting the aluminum down conductors to the copper or copper-covered grounding equipment are types specially designed for making the connection between the 2 dissimilar metals. The connection of the aluminum down conductors to the grounding equipment shall be made at a point not less than one foot above ground line. Protecting the connection from mechanical injury and displacement by the use of suitable guards is required.

(3) JOINTS. (a) *General.* Joints in conductors shall be as few in number as practicable and where they are necessary they shall be mechanically strong and well made and provide ample electrical contact. The latter requirement is to be regarded as met by a contact area not less than double the conducting cross-sectional area of the conductor.

Note: The following suggestions are offered in regard to the construction of joints in conductors.

1. Sections of cable conductor are preferably connected together by unravelling 6 inches or more of the ends and making a solderless wrapped joint. An alternative is found in couplings of malleable metal No. 14 AWG (0.064 inch) in thickness, 3 inches in length, and of semi-tubular form with projections on the interior which, when the coupling is crimped, become embedded in the cable.
2. Sections of tube conductor may be connected together by dowel-type screw joints with the dowels secured to the tube by rivets or by screw sleeve couplings.
3. Lengths of circular cross-section conductor may be connected together by the Western Union Joint with or without solder, McIntire Sleeves, or by screw couplings. Lengths of rectangular cross-section conductors (ribbon) may be connected together by overlapping and riveting.



McIntire Sleeve Joint
Above: Sleeve. Below: Completed Joint

4. Lengths of star-section conductor may be connected together by means of screw joints formed from lugs of metal crimped over or formed on the end of the conductor.
5. Branch conductors are best connected to main conductors by joints similar to those used in main conductors, except that they may be in T or Y form.

6. Elevation rods are best attached to cables by means of crimped joints of malleable metal, similar to those described in the first paragraph of this note, except that they should be in T form, and connect to the elevation rod by means of a dowel or screw coupling.

7. Elevation rods on forms of conductor other than cable may be attached in the same manner as branch rods, or by an equivalent means.

(b) *Mechanical strength.* On structures exceeding 60 feet in height, joints shall be so constructed that their mechanical strength in tension as shown by laboratory tests is not less than 50% of that of the smallest of the several sections of conductor which are joined together.

(c) *Electrical resistance.* Joints shall be so made that they have an electrical resistance not in excess of that of 2 feet of conductor.

(4) FASTENERS. (a) Conductors shall be securely attached to the building or other object upon which they are placed. Fasteners in general shall be substantial in construction, not subject to breakage and shall be, with the nails, screws, or other means by which they are fixed, of the same material as the conductor, or of such nature that there will be no serious tendency towards electrolytic corrosion in the presence of moisture because of contact between the different parts.

(b) Fasteners shall be so spaced as to give adequate support to the conductor, generally not over 4 feet apart.

Note 1. The firmness with which conductors are attached goes far toward determining their period of usefulness and security. Insecure fasteners not only lead to a reduction of the protective values of an installation but detract from its appearance and necessitate repeated repairs.

Note 2. Conductors may be secured to wood surfaces by means of metal bands or straps, screw-shank fasteners, or an equivalent means. Strap or band fasteners should be made, if of copper, from sheet metal not less than No. 20 AWG (0.032 inch) in thickness and not less than ⅜ inch wide; or if of aluminum, from sheet metal not less than No. 16 AWG (0.050 inch) in thickness and not less than ½ inch wide; with screw or nail holes surrounded by an ample width of material. Screw-shank fasteners should be provided with a fork of substantial construction which can be closed by bending. The screw-shank itself should be at least the equivalent in size of a No. 10 wood screw 1.5 inches long.

Note 3. Conductors may be secured to brick and stone surfaces by means of screw-shank fasteners in the form of an expansion screw, by drive-shank fasteners having the shank ridged or barbed to grip the hole when driven, or by fan-shank fasteners to be laid in the walls as they are built.

Note 4. Either the expansion screw or drive-shank should be not less than ⅜ inch in diameter and 2 inches in length, or of a type that will withstand a pull of at least 100 pounds. The fan-shank should be approximately ½ inch wide at its narrowest place, 1/10 inch thick and 3 inches long.

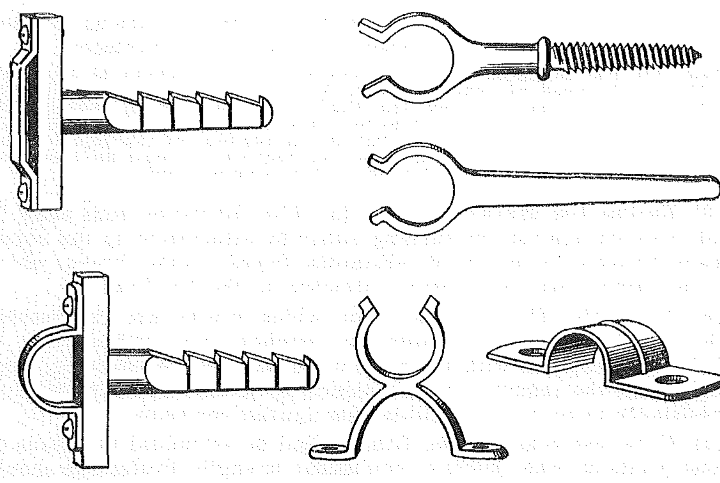
Note 5. Where screws are used they should be not smaller than No. 6, ¾ inch long. Nails should be not smaller in size than 4d standard. Copper-clad nails may be used with copper fasteners and galvanized nails with galvanized fasteners.

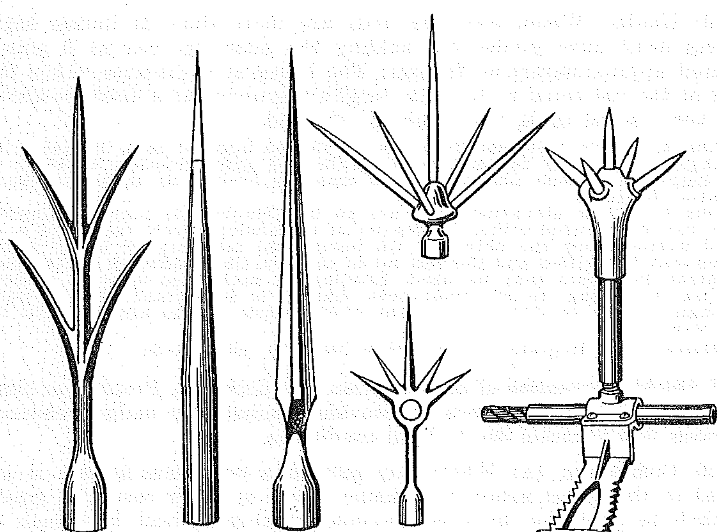
Note 6. Fasteners may also be leaded into masonry or brick work.

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.

E 161.02 Points and elevation rods. (1) ATTACHMENT OF POINTS. Separate points are not required, but if used shall be of substantial construction and be securely attached to the elevation rods by screw or slip joints. The conducting cross-sectional area of the base shall be at least equivalent to the conducting cross-sectional area of the elevation rod.

(2) ELEVATION RODS. (a) *Size.* Elevation rods shall be at least the equivalent in weight and stiffness of a copper tube having an outside diameter of ⅝ inch and a wall thickness of No. 20 AWG (0.032 inch).


Fasteners and Supports



Air Terminals

(b) *Form.* Elevation rods may be of any form of solid or tubular cross-section.

(c) *Height.* The height of an elevation rod shall be such as to bring the tip not less than 10 inches above the object to be protected.

Note: On flat surfaces a greater height than 10 inches is desirable but the height need not exceed 5 feet. In most cases the proper height for an elevation rod between the limits just mentioned will depend upon the character of the object to be protected. The proper height may also be taken as depending somewhat on the contour of the object being protected; a spire, for instance, does not require so high an elevation rod as a silo having a peaked but much less sloping roof.

(3) BRACES FOR ELEVATION RODS. (a) *Use.* Elevation rods shall be amply secured against overturning either by attachment to the object to be protected or by means of substantial tripod or other braces which shall be permanently and rigidly attached to the building.

(b) *Materials.* The material from which braces are constructed shall be at least the equivalent in strength and stiffness of ¼ inch round iron, and with the nails or screws used in erecting, shall comply with the requirements of section E 161.01 (1) MATERIALS as to resistance to corrosion or protection against corrosion.

(c) *Form and construction.* Braces shall be assembled by means of riveted joints or other joints of equivalent strength. Preference should be given to tripod or 4-legged braces and when in place the feet should be spread until the distance between them approximates ⅓ the height of the brace.

(d) *Guides.* Where elevation rods are more than 24 inches high, braces shall have guides for holding the elevation rod at 2 points located approximately as follows: The lower at a distance above the foot of the rod equal to ⅓ of its height, the upper at a distance above the lower equal to ¼ the height of the rod.

Note 1. Where elevation rods are 24 inches high or less, braces with a single guide may be used, holding the rod approximately midway of its height. Ten-inch elevation rods may be braced by means of substantial footings.

Note 2. Where elevation rods are to be attached to house chimneys they can be secured either by means of expansion screw fasteners or a band surrounding the chimney. On horizontal masonry or brick work, holes may be drilled and the rod set in cement. On woodwork lag-screws or strap fasteners may be used. Bracing in each case may be accomplished according to circumstances, but it is important that a good mechanical job be done to prevent overturning of the air terminal by the wind.

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.

E 161.03 Prevention of deterioration. (1) GENERAL. Precaution shall be taken in every instance to provide against any undue tendency towards deterioration due to local conditions.

(2) CORROSION. (a) Where any part of a protective system is exposed to the direct action of chimney gases or other corrosive gases, it shall be protected by a continuous covering of lead 1/16 inch or more in thickness.

(b) Aluminum parts, including fasteners and anchors, shall be protected from direct contact with concrete or mortar wherever such concrete or mortar is wet or damp, or may become intermittently wet or damp.

(3) MECHANICAL INJURY. Where any part of a protective system is exposed to mechanical injury it shall be protected by covering it

with molding or tubing preferably made of wood or non-magnetic material. If metal tubing is used the conductor shall be electrically connected to it at its upper end.

(4) USE OF ORNAMENTS. The use of small ornaments such as glass balls attached to elevation rods is not objectionable but elevation rods shall not be made to support vanes or ornaments having in any plane a wind-resistance area in excess of 20 square inches.

Note: Twenty square inches of area as a maximum for an ornament represents approximately the wind resistance area of a 5-inch glass ball. Where heavy or large ornaments are desired they should be provided with a separate support.

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.

E 161.04 Air terminals and conductors. (1) GENERAL. Air terminals shall be provided for all structural parts that are likely to receive, and be damaged by, a stroke of lightning.

(2) PROJECTIONS. In the case of projections such as gables, chimneys, and ventilators, the air terminal shall be placed on, or attached to, the object to be protected where practicable, otherwise within 2 feet of it.

(3) RIDGES, PARAPETS, AND EDGES OF FLAT ROOFS. Along ridges, parapets, and edges of flat roofs, air terminals shall be spaced at intervals not exceeding 25 feet.

(4) METAL PROJECTIONS AND PARTS OF BUILDINGS. Metal projections and parts of buildings such as ventilators, smokestacks, and other objects, that are likely to receive, but not be appreciably damaged by, a stroke of lightning, need not be provided with air terminals, but shall be securely bonded to the lightning conductor with metal of the same weight per unit length as the main conductor.

Note 1. Parts of structures most likely to be struck by lightning are those which project above surrounding parts such as chimneys, ventilators, flagpoles, towers, water-tanks, spires, steeples, deck-railings, shaft-houses, gables, skylights, dormers, ridges and parapets.

Note 2. The edge of the roof is the part most likely to be struck on flat-roofed buildings. On large flat and gently sloping roofs it is desirable to erect air terminals at points of intersection of lines dividing the surface into rectangles not exceeding 50 feet in length.

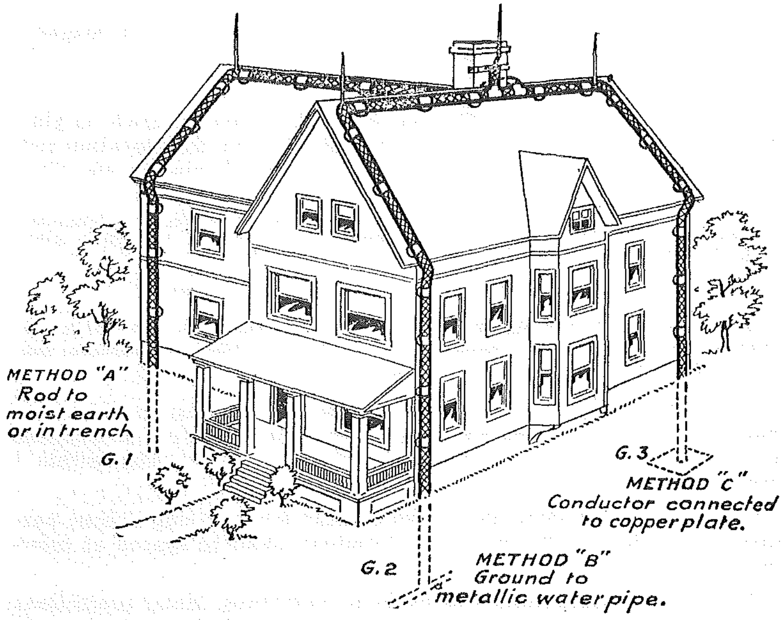
Note 3. In parts of some buildings relatively thin layers of brick, stone, tile or similar masonry material have been laid on top of structural steel. Lightning then has to break through the brick, stone, etc., to reach the steel, and this may result in fragments of brick, stone, etc., being thrown down into the street. Such construction should be avoided, but where already existing, the situation may be improved by covering the masonry with a metallic sheathing, which in turn is connected to the lightning protective system.

(5) COURSING OF CONDUCTORS. Conductors shall in general be coursed over the roofs and down the corners and sides of buildings in such a way as to constitute as nearly as local conditions will permit, an enclosing network.

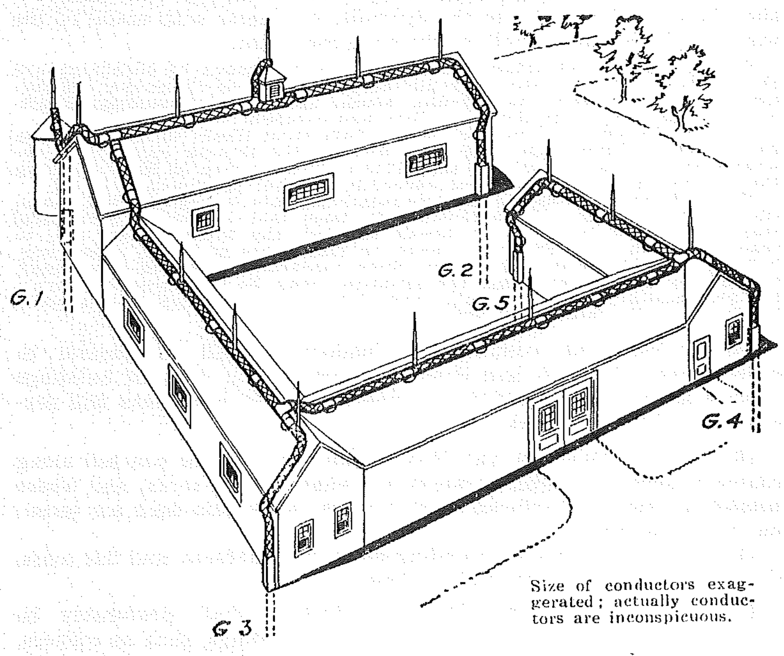
(6) ROOF CONDUCTORS. (a) Roof conductors shall be coursed along contours, such as ridges, parapets and edges of flat roofs, and where necessary over flat surfaces, in such a way as to join each air terminal to all the rest.

(b) Roof conductors surrounding decks, flat surfaces, and flat roofs, shall be connected to form a closed loop.

(7) DOWN CONDUCTORS. Down conductors shall preferably be coursed over the extreme outer portions of buildings, such as corners,



Typical Installation on Large Dwelling
(Size of Conductors exaggerated in the drawing)



Size of conductors exaggerated; actually conductors are inconspicuous.

Typical Installation on Barn Group

due consideration being given to the best places for making ground connections, and to the location of air terminals.

(8) OBSTRUCTIONS. Horizontal conductors shall be coursed around chimneys, ventilators, and similar obstructions in a horizontal plane and without abrupt turns.

(9) BENDS. No bend in a conductor which embraces a portion of a building such as an eave, shall have a radius of less than 8 inches. The angle of any turn shall not exceed 90° and conductors shall everywhere preserve a downward or approximately horizontal course.

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.

E 161.05 Metal-roofed and metal-clad buildings. The materials and equipment required by this rule for the protection of metal-roofed or metal-roofed and clad buildings, shall comply with the requirements of sections E 161.01 to E 161.04, inclusive.

(1) METAL NOT CONTINUOUS. Buildings which are roofed, or roofed and clad, with metal in the form of sections insulated from one another, or so applied that they are not in electrical contact, shall be treated in the same manner as are buildings composed of non-conducting materials.

(2) METAL CONTINUOUS. When buildings are roofed or roofed-and-clad, with all-metal sheets made electrically continuous by means of an interlocking or other contact acceptable to the administrative authority, or by bonding, the following modifications may be made to the requirements of sections E 161.02 to E 161.08, inclusive.

(a) Air terminals need be provided only on chimneys, ventilators, gables, and other projections, such as are likely to receive and be damaged by a stroke of lightning. Projections that are likely to receive, but not be damaged by a stroke of lightning need not be provided with air terminals, but shall be securely bonded to the roof.

(b) Roof conductors may be dispensed with, and elevation rods, if used connected to the roof by soldered joints, or securely bolted joints, having an area of contact of not less than 3 square inches. If the roof metal is in small sections, connection shall be made to at least 4 of the sections.

(c) Down conductors shall be connected to the edges of roofs, or to the lower edges of metal siding, by soldered or bolted joints having an area of contact of at least 3 square inches. If the metal is in small sections, connection shall be made to at least 4 of the sections.

(d) The roof metal should have adequate thickness (See section E 171.02) to prevent a hole being burned in the metal in case of a direct stroke to the roof, which could cause a fire if flammable material were stored below.

(3) METAL ROOF NOT ELECTRICALLY CONTINUOUS WITH METAL SIDING. The siding shall be connected to the roof at each corner, and down conductors shall be connected to the lower part of metal siding, in the manner specified in subsection (2) above, with a connection between roof and siding directly above the down conductor in every case, and the down conductor grounded as specified in section E 161.08.

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.

E 161.06 Number of down conductors. (1) MINIMUM. There shall be not less than 2 down conductors on any type of buildings, and these shall be run so as to be as widely separated as practicable. The following rules shall apply as to additional down conductors.

Note: In deciding upon the location and number of down conductors it should be kept in mind that it is very desirable to have at least 2 paths in parallel, and well separated, from the foot or near the foot of each air terminal to ground. This causes a stroke upon any air terminal to find a divided path the impedance of which is less than that offered by a single path and affords increased protection. The obstruction, or impedance, offered to the passage of the stroke is nearly in inverse proportion to the number of parallel paths if they are well separated.

(2) RECTANGULAR STRUCTURES. (a) On rectangular structures having gable, hip, or gambrel roofs, and exceeding 110 feet in length, there shall be at least one additional down conductor for each additional 50 feet of length, or fraction thereof.

(b) On rectangular structures having French, flat, or sawtooth roofs, and exceeding 300 feet in perimeter, there shall be at least one additional down conductor for each additional 100 feet of perimeter or fraction thereof.

(3) IRREGULAR-SHAPED STRUCTURES. (a) On an ell or T-shaped structure there shall be at least one additional down conductor; on an H-shaped structure at least 2 additional down conductors; and on a wing-built structure at least one additional down conductor for each wing.

(b) On irregular-shaped structures the total number of down conductors shall in every case be sufficient to make the average distance between them along the perimeter not greater than 100 feet.

(4) STRUCTURES EXCEEDING 60 FEET IN HEIGHT. On structures exceeding 60 feet in height there shall be at least one additional down conductor for each additional 60 feet of height, or fraction thereof, except that the application of this rule shall not cause down conductors to be placed about the perimeter of a structure at intervals of less than 50 feet.

(5) METAL-ROOFED AND METAL-CLAD BUILDINGS. The number of down conductors and ground connections for metal-roofed and metal-clad buildings shall be determined in the same manner as for buildings composed of non-conducting materials, i.e. according to the requirements of subsections (1), (2), (3) and (4) above.

(6) DEAD ENDS. Additional down conductors shall be installed where necessary to avoid "dead ends", or branch conductors ending at air terminals, which exceed 16 feet in length, except that single down conductors descending flagpoles, spires, and similar structures which are adjuncts of buildings shall not be regarded as "dead ends" but shall be treated as air terminals.

Note 1. Dead ends arise where an air terminal is placed on the peak of a dormer, or in some similar situation, and in the interest of economy is connected only to the nearest conductor, which usually is at the nearest ridge. A stroke on such an air terminal must traverse a single conductor until it reaches the ridge conductor where the path divides. The foregoing rule allows 16 feet for the length of this single conductor. Where greater lengths are encountered the conductor must be extended from the air terminal to ground.

Note 2. It is advisable to install additional down conductors at places along runs of roof conductors where the roof conductor descends into low places between parts of buildings as it may in the case of an H-shaped structure where the end wings are higher than the connecting portion.

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.

E 161.07 Interconnection of metallic masses. (1) INTERCONNECTION OR GROUNDING. Metallic masses about buildings which are a permanent portion of the structure, or are permanently installed within or about it, shall, with the exception of those of comparatively small size, be made a part of the lightning-conductor system by interconnection with it, or be independently grounded, or both, depending upon their location with respect to the lightning conductors and their surroundings as more fully described in subsections (2) to (8) inclusive of this rule.

Note: The object of interconnecting the metal parts of a building with the conductor is to prevent the damage from side flashes that has been found to occur, especially in the case of rather extensive metal objects that are nearby. The main principle to be observed in the prevention of such damage is to pick out on a building the places where side flashes are most likely to occur and provide metallic paths for them.

(2) EXTERIOR BODIES OF METAL. Metal situated wholly on the exterior of buildings shall be electrically connected to the conductor at its upper (or nearest) end, and if of considerable length, shall be grounded or electrically connected to the conductor at its lower (or farthest) end.

Note: Exterior bodies of metal include ornamental ridges, ventilators, roofs, valleys, gutters, down spouts, and structural iron. Connecting these into the lightning conductor system not only serves to prevent side flashes that cause damage, but makes the system a nearer approach to an enclosing network.

(3) INTERIOR BODIES OF METAL. Metal situated wholly in the interior of buildings which at any point comes within 6 feet of a lightning conductor, or metal connected thereto, shall be electrically interconnected with it, and if of considerable size or length shall be grounded at its lower or farther extremity within the building.

Note: Interior bodies of metal include radiators, piping systems, tanks, stationary machinery, stanchions, and various forms of structural metal. In general, experience has shown that side flashes are not likely to occur to bodies of metal of ordinary size located more than 6 feet from a conductor, whereas those that are nearer are likely to receive side flashes which may damage a building or set fire to it. Very long or very large bodies of metal may, however, be a menace at more than 6 feet. The side flashing to these nearby bodies is eliminated by interconnection but the rise of potential due to dynamic discharges is not, so interior grounding becomes necessary. Unless there are water pipes or their equivalent that may be used for interior grounding purposes there may be danger to persons and livestock about dwelling houses and barns. On this account where water pipes are not available it is advisable to avoid as far as practicable the necessity for interconnection of interior bodies of metal by keeping conductors more than 6 feet away from them—the farther the better.

(4) METAL BODIES PROJECTING THROUGH SIDES AND ROOFS. (a) Metal which projects through roofs, or through sides of buildings above the second floor, shall be bonded to the nearest conductor at the point where it emerges from the building and be grounded at its lower or extreme end within the building.

(b) Metal which projects through the sides of buildings below the second floor shall be treated as though it were wholly within the building.

Note: Metal projections through roofs and sides of buildings generally consist of soil pipes, metal flues, over-flow pipes of hot-water heating systems and isolated gravity-type water systems, hayfork tracks and ventilators. Hayfork tracks may be taken care of by connecting both ends to the conductor.

(5) INTERCONNECTION OF METALS ON OR WITHIN METAL-ROOFED AND METAL-CLAD BUILDINGS. (a) All parts of metal roofs, or roofs and sides, shall be securely bonded together.

(b) All interior metal parts or contents of considerable size or extent that are a permanent portion of a structure or are permanently installed within it, shall be independently grounded, and if within 6 feet of sides or roof or a down conductor shall be connected thereto.

Note: The necessity for interconnecting and grounding the metal contents of metal-roofed and metal-clad buildings arises from the fact that in the event of a discharge the potential of the metal covering, even though grounded, changes sufficiently with respect to nearby objects to cause side flashes, especially where the distance to be covered by the flash is short. Side flashes from the metal coverings of buildings are likely to be especially destructive or dangerous because of the large electrostatic capacity involved. The chances for such side flashes should be particularly considered in all buildings housing dusty operations, as flour mills. Care should be taken to ground ventilators projecting downward from roofs.

(6) METALLIC BODIES TO BE INDEPENDENTLY GROUNDED. Metallic bodies having any dimension exceeding 5 feet, and situated wholly within buildings, and which do not at any point come within 6 feet of a lightning conductor or metal connected thereto shall be independently grounded.

Note: It is generally safest to ground all metal within buildings that does not come close enough to a conductor to require interconnection with it, using an independent ground connection of any of the usual types, for the reason that it prevents sparks from accumulated static charges and from induction due to dynamic discharges.

(7) SUBSTITUTION FOR REGULAR CONDUCTORS. Extended metal parts of buildings shall not be substituted for regular conductors, except where they are permanently electrically continuous, and have a conducting cross-sectional area at least double that of the lightning conductor that would otherwise be used.

Note: In some cases of monumental structures and others where heavy and extensive metal parts are available they may well be used in place of conductors to avoid expense and sacrifice of appearance, there being no difference whether they are on the interior or exterior of the structure where used for down conductors.

(8) SIZE OF INTERCONNECTING AND BONDING WIRES. For bonding, interconnecting and independent grounding of metallic masses the conductor used shall be at least the equivalent in strength and conducting cross-sectional area of a No. 6 AWG copper wire, except where full-size lightning conductor is required by subsection E 161.04 (4).

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.

E 161.08 Ground connections. (1) NUMBER. A ground connection shall be provided for each down conductor, preference being given to metal water pipes and other large underground metallic structures.

(2) DISTRIBUTION. Ground connections (and down conductors) shall be placed at as uniform intervals about a building as practicable, and grouping of ground connections on one side of a building avoided.

(3) MOISTURE. In making ground connections advantage should be taken of all permanently moist places where practicable, although such places should be avoided if wet with waste water which contains chemical substances especially corrosive to the metal with which the ground connection is made.

Note: Chemical substances especially corrosive to lightning conductor material are not ordinarily encountered in practice. They would usually be found about factories engaged in chemical processes.

(4) PERMANENCY. Ground connections shall in every case be thoroughly and permanently made, with due regard to the character of the surrounding soil.

(5) WATERPIPE GROUNDS. Where a metallic waterpipe enters a building at least one down conductor shall be connected to it, preferably at a point immediately outside of the foundation wall, by means of a substantial clamp to which the conductor can be attached by bolts or solder.

(6) GROUNDING ELECTRODES IN DEEP SOIL. Where the soil is moist clay, or other soil of similar character as to electrical resistivity, artificial grounding electrodes may be made by extending the rod itself into the ground a distance of not less than 10 feet. Where the soil is largely sand, gravel, or stones, more extensive artificial grounding electrodes shall be made by adding metal in the form of driven rods or pipes, or strips, plates, or lengths of conductor buried in trenches as in subsection (7). Where a grounding electrode consists of a driven rod or pipe, the length of the electrode shall be permanently marked upon it at the top.

(7) GROUNDING ELECTRODES IN SHALLOW SOIL. Where bed rock is near the surface, ground connections may be made by digging trenches radially from the building and burying in them the lowest ends of the down conductors or their equivalent in the form of metal strips or wires. Where the soil is very dry or will not permit digging to a depth of more than one foot, in addition to the conductors laid radially, a similar conductor shall be buried which encircles the structure to be protected and connects all of the down conductors together.

(8) TRENCHES. Trenches shall be long enough to accommodate 12 feet of conductor when laid straight, but need not be more than 3 feet in depth.

Note 1. Properly made ground connections are essential to the effective functioning of a lightning-conductor system and every effort should be made to provide ample contact with the earth. This does not necessarily mean that the resistance of the ground connection must be low, but rather that the distribution of metal in the earth or upon its surface in extreme cases, shall be such as to permit the dissipation of a stroke of lightning without damage.

Note 2. Low resistance is, of course, desirable, but not essential, as may be shown by the extreme case on the one hand of a building resting on moist clay soil, and on the other by a building resting on bare solid rock. In the first case if the soil is of normal resistivity or from 200 to 5000 ohm-centimeters, the resistance of a ground connection made by extending the conductor 10 feet into the ground will be from 20 to 50 ohms, and 2 such ground connections on a small rectangular building have been found by experience to be sufficient. Under these favorable conditions providing adequate means for collecting and dissipating the energy of a flash without serious chance of damage is a simple and comparatively inexpensive matter.

Note 3. In the second case it would be impossible to make a ground connection in the ordinary sense of the term because most kinds of rock are insulating, or at least of high resistivity, and in order to obtain the effect of grounding other and more elaborate means are necessary. The most effective means would be an extensive wire network laid on the surface of the rock surrounding the building, after the manner of counterpoise to a radio antenna, to which the down conductors, could be connected. The resistance to earth at some distant point of such an arrangement would be high but at the same time the potential distribution about the building would be substantially the same as though it were resting on conducting soil and the resulting protective effect also substantially the same.

Note 4. In general, the extent of the grounding arrangements will depend upon the character of the soil, ranging from simple extension of the conductor into the ground where the soil is deep and of high conductivity, to an elaborate buried network where the soil is very dry or of very poor conductivity. Where a network is required it should be buried if there is soil enough to permit it, as this adds to its effectiveness. Its extent will be determined largely by the judgment of the person planning the installation with due regard to the minimum requirements of this rule, which is intended to cover the ordinary run of cases that are likely to be encountered in practice, keeping in mind that as a rule the more extensive the underground metal available the more effective the protection.

Note 5. Some essential features of good practice in grounding for protection against lightning are as follows:

1. Where practicable each artificial ground connection should extend or have a branch which extends below and at least 2 feet away from the foundation walls of the building, as otherwise there is a chance of the wall being damaged.

2. The metal composing the ground connection should make contact with the soil from the surface downwards, for if contact is made below the surface there may be flashing at the surface with danger of burning off the conductor.

3. During a stroke of lightning on a system of conductors the grounding electrodes are to be thought of as the point through which the heavy current flows between the air terminals and the surface of the earth about the building and should, therefore, be distributed with the view of carrying this flow of current in the most advantageous manner. This will be generally realized by placing them at the outer extremities, such as the corners, and avoiding as far as possible the necessity for current flow under the building.

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.

E 161.09 Radio installations and wires entering buildings. (1) WIRES ENTERING BUILDINGS. Wires entering buildings shall conform to requirements of the latest edition of the Wisconsin State Electrical Code which are applicable.

(2) METAL RADIO MASTS ON BUILDINGS. Metal radio masts on buildings shall be bonded to the nearest lightning conductor.

(3) WOODEN RADIO MASTS. Wooden radio masts which extend more than 6 feet above the ridge or highest parts of the building on which they are placed shall be treated in the same manner as flag poles.

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.

E 161.10 Concealed installations. (1) FULL CONDUCTOR SYSTEMS. (a) The same requirements as for exposed systems apply to concealed systems. Conductors are coursed the same except that they may be under the roofing material, under the roof, behind the exterior wall facing or between the studs of walls.

(b) Groundings may be carried to the exterior at or below grade level and then made in the conventional manner according to soil conditions encountered. Groundings may also be placed in the basement below the basement slab but on outside walls only. Such groundings below basement slabs should be avoided at interior locations in the structure due to the fact that the soil in such locations will usually be dry.

(c) Chimney points and chimney conductors may be built into the masonry of the chimney or may be attached to the exterior of the chimney and then carried through the roof to the interior main conductor.

(d) Approved fittings and flashings shall be employed in making all through roof and through wall connections. Particular care should be employed on concealed installations to insure common grounding of all extended metallic parts such as the electric system, water system, furnace pipes or ducts, gas pipes, soil pipes, metal lathing, foil insulation, etc.

(2) STRUCTURAL STEEL SYSTEMS. (a) The structural steel framework of a building may be utilized as the main conductor of a lightning protection system provided it is electrically continuous or is made electrically continuous by bonding of non-electrically continuous sections. The electrical continuity may be measured by a comparison of ohms resistance to ground at ground level and at the top and other elevations of the structure. Electrically continuous reinforcing rods may also be considered as structural steel.

(b) Air terminals may be individually bonded to the framework through the roof or parapets or they may be joined together with an exterior conductor which shall be bonded to the framework in not less than the same number of places as there are groundings for the structure.

(c) Groundings shall be made from approximately every other steel column, around the perimeter, and in no case shall they average more than 60 feet apart.

(d) All bondings of air terminals, connecting conductors, and grounding tails shall be made to the steel with bonding plates having a surface contact of not less than 8 square inches. They shall be bolted, welded, brazed or securely clamped to a cleaned section of the steel.

(e) If the grounding locations are dry, such as in sand, gravel, or rock, a counterpoise, interconnected with each of the individual ground terminals shall be installed.

History: Cr. Register, April, 1964, No. 100, eff. 5-1-64.